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291
UNIVERSAL
IMPEDANCE BRIDGE
INSTRUCTION MANUAL

ELECTRO-MEASUREMENTS, INC.
7524 S.W. MACADAM AVE.
PORTLAND 1, OREGON

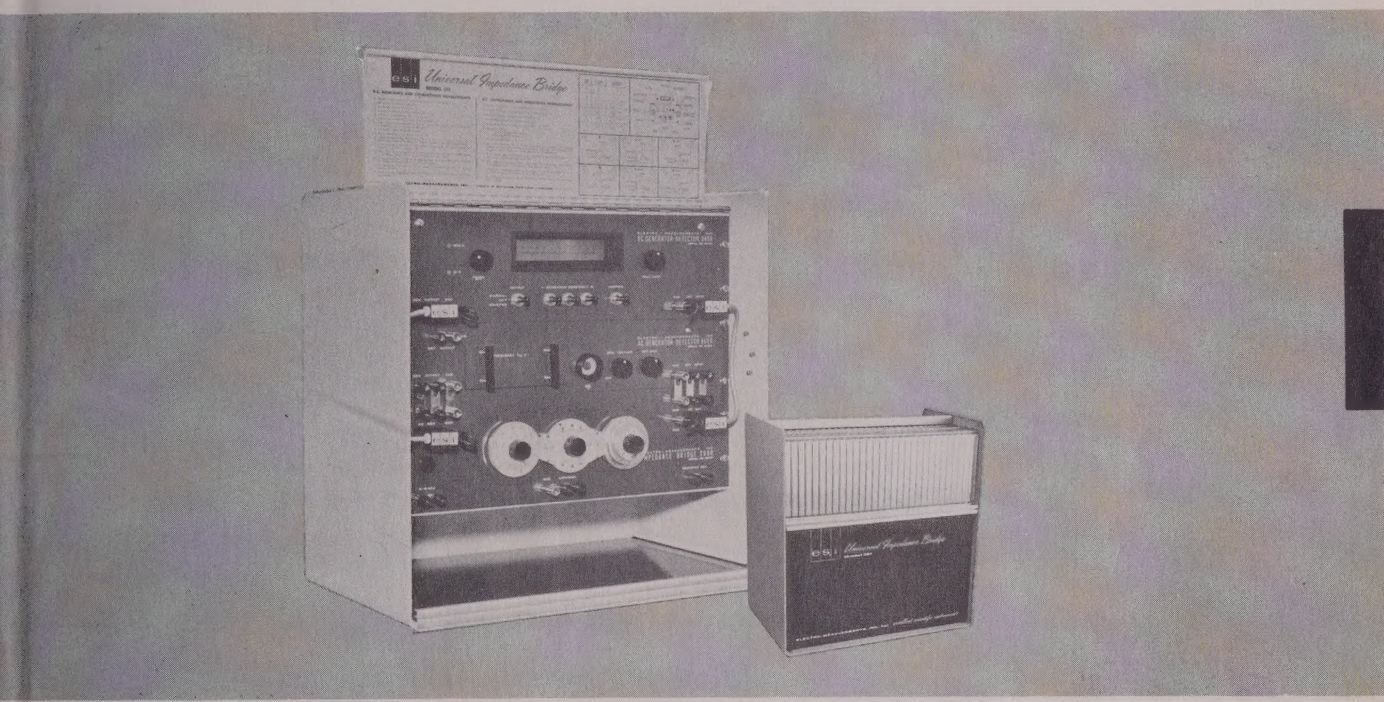
102

esi *Instruction Manual*

BRIDGES
AND
ACCESSORIES

ELECTRO - MEASUREMENTS INC.
7524 S. W. MACADAM • PORTLAND, OREGON

August 1958



Model 291

IMPEDANCE BRIDGE

including

Model 290-R

IMPEDANCE BRIDGE

Model 840-R

DC GENERATOR-DETECTOR

Model 860-R

AC GENERATOR-DETECTOR

excellent scientific instruments

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INSTRUCTION MANUAL
for
MODEL 291 IMPEDANCE BRIDGE

CONSISTING OF:

Catalog Sheet C-13 including:

Introduction

Specifications

Model 290-R Impedance Bridge Instruction Manual

Model 840-R Instruction Manual

Model 860-R Instruction Manual

Lid Instructions from 291 Bridge

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Catalog Sheet

BRIDGES AND ACCESSORIES

C-13

ELECTRO-MEASUREMENTS, INC.
7524 S. W. MACADAM • PORTLAND 1, OREGON

JUNE 1957

Combined units with cabinet as pictured . . . MODEL 291

MODEL 290-R RACK-MOUNTED

universal impedance bridge

WITH MODEL 840-R D.C. GENERATOR-DETECTOR

AND MODEL 860-R A.C. GENERATOR-DETECTOR

Versatile and accurate in the lab and on the production line

The ESI Model 290-R bridge is a rack-mounted, general-purpose impedance bridge. It offers high accuracy and great flexibility of measurement. The controls have been human-engineered for maximum operator convenience. Simple operation and error-free, direct-line readout are made possible by the ESI DEKADIAL® coaxial controls.

The bridge measures resistance, conductance, capacitance, and inductance. For capacitors and inductors, it also measures the dissipation factor (D) and storage factor (Q).

The ESI Model 840-R dc generator-detector and Model 860-R ac generator-detector units are especially designed for use with this bridge.

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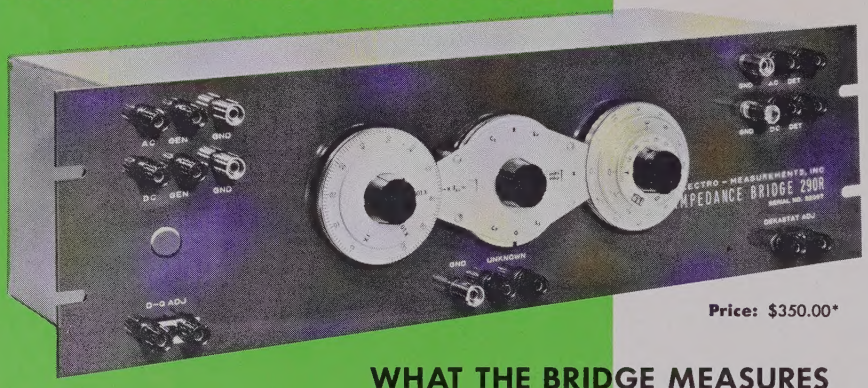
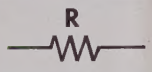
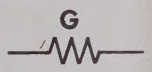
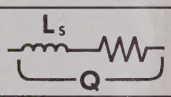
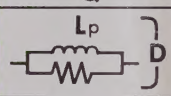
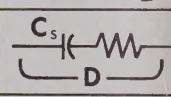
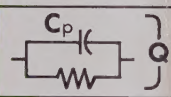
MODEL 290-R
UNIVERSAL IMPEDANCE BRIDGE



Price: $350.00*

Panel width: 19″, fits standard rack. Panel height: 5¼″. Depth behind panel: approximately 8″. Weight: 18½ lbs. net.

SELECTOR SWITCH SETTING	EQUIVALENT CIRCUIT
R	
G	
L Series	
L Parallel	
C Series	
C Parallel	

WHAT THE BRIDGE MEASURES

The Model 290-R impedance bridge measures resistance, conductance, inductance, and capacitance. It also measures the dissipation factor (D) and the storage factor (Q) of inductors and capacitors.

Resistance and conductance measurements are usually made with direct current because of the increased accuracy and the lack of stray reactance effects. Resistance and conductance measurements can be made using ac, but they may require external reactance compensation.

Inductance and capacitance measurements are made in terms of a simple two-element circuit with the same impedance as the unknown. The bridge dials read the values of this equivalent circuit. An equivalent parallel circuit is used for high Q inductors and high D capacitors. An equivalent series circuit is used for low D capacitors and low Q inductors.

MODEL 840-R
D.C. GENERATOR-DETECTOR

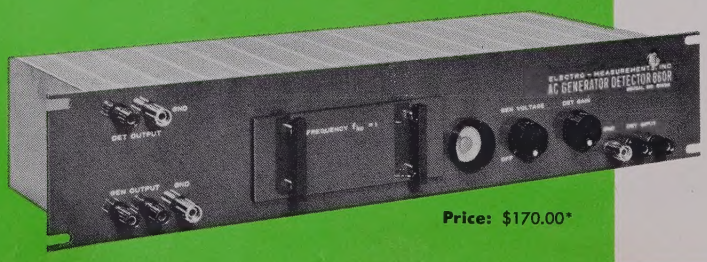
Price: $175.00*

The ESI Model 840-R DC Generator and Detector unit is a combination of a power supply and a sensitive galvanometer. The 840-R was designed as an accessory to the ESI Model 290-R Impedance Bridge. It is also useful for other measurements. For example, it can be used with the ESI 260 or 260-R Comparison Bridge for dc resistance comparisons. It can also be used for comparing voltage dividers and potentiometers.

The generator section supplies 10 v for low resistance loads, and 300 v for high resistance loads. A polarity reversing switch has been added for measurement convenience. Generator insulation greater than 10,000 megohms.

The detector section consists of a light beam galvanometer and associated zero-set, damping, and sensitivity controls.

MODEL 860-R
A.C. GENERATOR-DETECTOR



Price: $170.00*

The ESI Model 860-R Generator and Detector unit is a combination of an ac generator and a sensitive null indicator. The 860-R was designed as an accessory to the ESI Model 290-R Impedance Bridge. It is also useful for other measurements. For example, it can be used with any ac bridge as an auxiliary generator and detector unit.

The generator section supplies a variable-voltage variable-frequency well insulated power source for ac bridge measurements.

The detector section consists of a high-gain tuned amplifier and wide range dual electron ray null indicator.

*Complete unit, model 291 as pictured on front page, with customed enclosure . . . priced at $775.00.

All prices f.o.b. Portland, Oregon.

SPECIFICATIONS

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MAGNITUDE		D and Q	
RANGE	**ACCURACY**	**RANGE**	**ACCURACY**
0-1200 kilohms in 7 ranges* 0.1 milliohm per dial division on lowest R range	± (0.1% + 1 dial div.), except ± (0.2% + 1 dial div.) on lowest R range		
0-1200 millimhos in 7 ranges 100 μμmhos (1/10,000 megohms) per dial division on lowest G range	± (0.1% + 1 dial div.), except ± (0.2% + 1 dial div.) on lowest G range		
0-1200 henrys in 7 ranges 0.1 μh per dial division on lowest L range	± (0.3% + 1 dial div.), except ± (0.4% + 1 dial div.) on lowest L range	$Q = 0$ to $10.5 \times f_{kc}$ in 3 ranges $0.001 \times f_{kc}$ per dial division on lowest Q range	$1/Q = \pm(2\% + 0.01 \times f_{kc})$ except $\pm(2\% + 0.04 \times f_{kc})$ on highest L range
0-1200 henrys in 7 ranges 0.1 μh per dial division on lowest L range	± (0.3% + 1 dial div.), except ± (0.4% + 1 dial div.) on lowest L range	$D = 0$ to $10.5 \times f_{kc}$ in 3 ranges $0.001 \times f_{kc}$ per dial division on lowest D range	$D = \pm(2\% + 0.01 \times f_{kc})$, except $\pm(2\% + 0.04 \times f_{kc})$ on highest L range
0-1200 microfarads in 7 ranges 0.1 μμf per dial division on lowest C range	± (0.2% + 1 dial div.), except ± (0.3% + 1 dial div.) on highest C range	$D = 0$ to $10.5 \times f_{kc}$ in 3 ranges $0.001 \times f_{kc}$ per dial division on lowest D range	$D = \pm(2\% + 0.01 \times f_{kc})$, except $\pm(2\% + 0.04 \times f_{kc})$ on lowest C range
0-1200 microfarads in 7 ranges 0.1 μμf per dial division on lowest C range	± (0.2% + 1 dial div.), except ± (0.3% + 1 dial div.) on highest C range	$Q = 0$ to $10.5 \times f_{kc}$ in 3 ranges $0.001 \times f_{kc}$ per dial division on lowest Q range	$1/Q = \pm(2\% + 0.01 \times f_{kc})$ except $\pm(2\% + 0.04 \times f_{kc})$ on lowest C range

*Equivalent resistance measurements to 10,000 megohms are possible using the conductance ranges.

Accuracy statements apply at 1 kc. Errors may be slightly larger at frequency extremes.

GENERATOR

Voltages: Dc outputs of 10 volts with internal resistance of 60 ohms and 300 volts with internal resistance of 22K ohms.

Power: Power output limited to 1 watt by internal series resistance.

Polarity: Polarity of voltage at output terminals may be reversed by a front panel control.

DETECTOR

Galvanometer: The light beam type galvanometer has a sensitivity of approximately 30 millimeters per microampere. It has an internal resistance of approximately 300 ohms, and is critically damped by approximately 2,000 ohms.

Sensitivity: Three-position switches on the front panel select the desired galvanometer sensitivity. Sensitivities available are 0.03, 0.60, and 12 microamperes per millimeter division.

Zero-Set: A knob on the front panel provides for adjustment of the galvanometer zero position.

Damping: A three-position switch on the front panel selects the damping condition when using maximum galvanometer sensitivity.

POWER SUPPLY

115 volts or 230 volts, 50/60 cycles. Voltage choice is by means of internal wiring change.

PROTECTION

Circuit is designed so dc power output, at either 10 volts or 300 volts, cannot exceed 1 watt. Detector cannot be damaged by power from 840-R generator section.

DIMENSIONS — MOUNTING

Instrument is designed for standard racks having 19" width; panel height 5¼"; depth behind panel approximately 8". Weight is 12 pounds net.

GENERATOR

Voltage: The generator voltage is adjustable from 0 to approximately 15 volts, with an internal resistance of approximately 600 ohms. Each generator output terminal is insulated from ground and has a capacitance to ground of less than 30 micromicrofarads.

Frequency: The operating frequency is determined by the plug-in network, and is accurate to ±1%. A 1 kilocycle unit is supplied with the bridge. Units for 0.1, 0.4, and 10 kilocycles are available from stock. Special networks for any freqency between 0.1 and 10 kilocycles can be made to order.

DETECTOR

Indicator: An electron ray null indicator is used because of its instantaneous response to signal changes. This prevents passing a null without knowing it. A dual display presents changes in either strong or weak signals.

Sensitivity: At maximum detector gain the lower half of the eye responds to signals between approximately 20 microvolts and 0.01 volts. The upper eye responds to signals between 0.01 volts and 5 volts.

Frequency: The detector is sharply tuned to the generator frequency in order to minimize response to harmonics and hum pickup. The detector and generator tuning networks are contained in the same plug-in unit. The detector response to the second harmonic of the generator frequency is down at least 30 decibels.

POWER SUPPLY

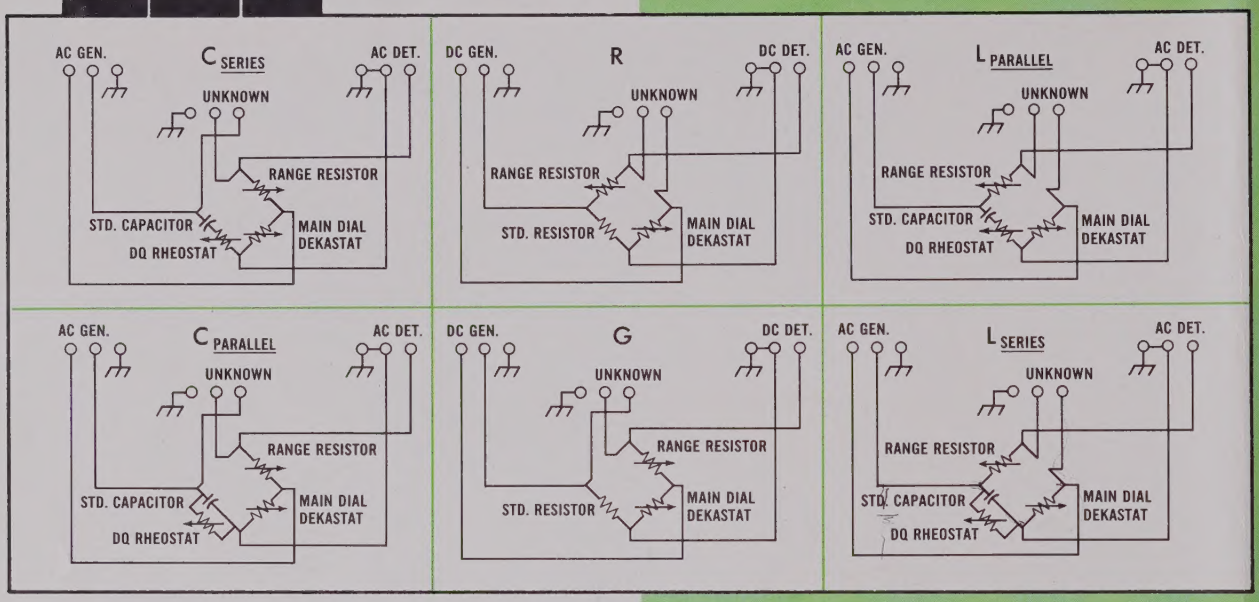
115 volts, 50/60 cycles. 230 volt transformer is available.

DIMENSIONS — MOUNTING

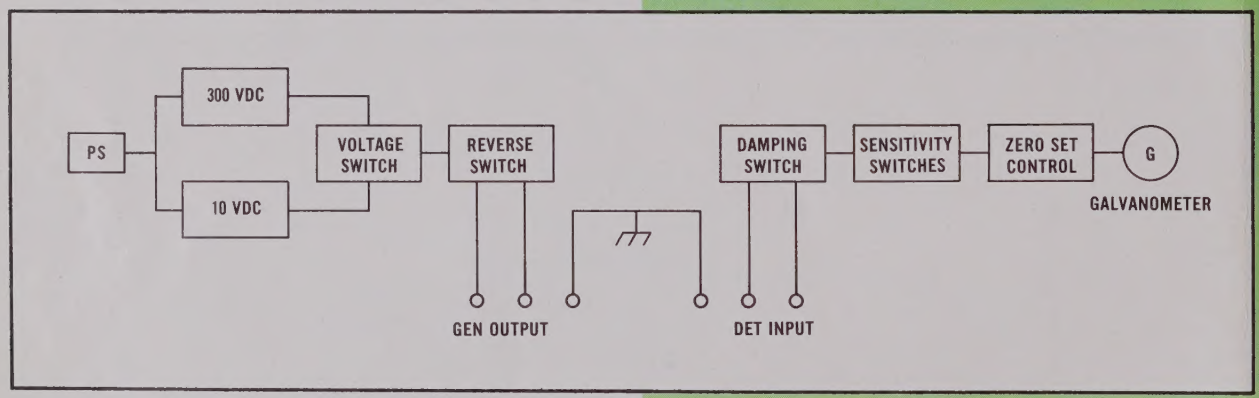
Instrument is designed for standard racks having 19" width; panel height 3½"; depth behind panel approximately 8". Weight is 10 pounds net.

CIRCUIT DIAGRAMS

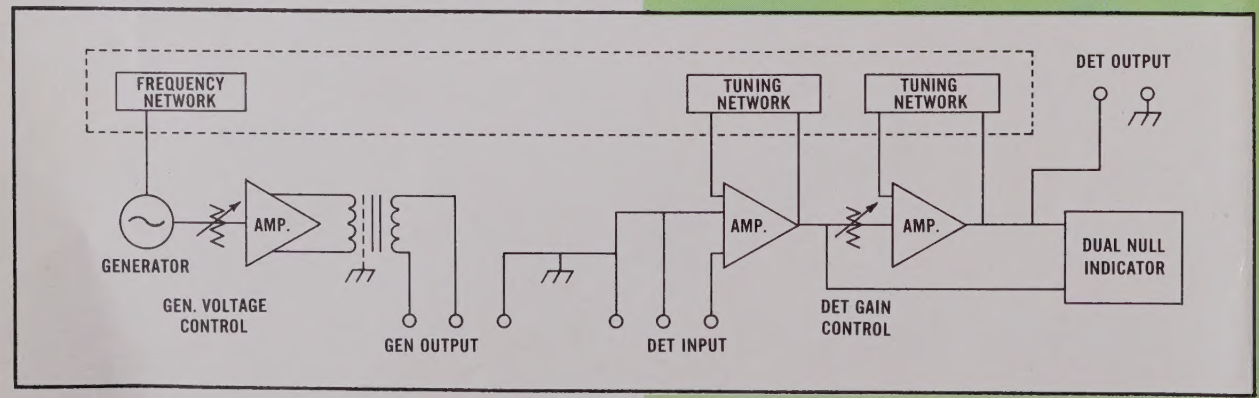
MODEL 290-R IMPEDANCE BRIDGE



MODEL 840-R D. C. GENERATOR-DETECTOR



MODEL 860-R A. C. GENERATOR-DETECTOR



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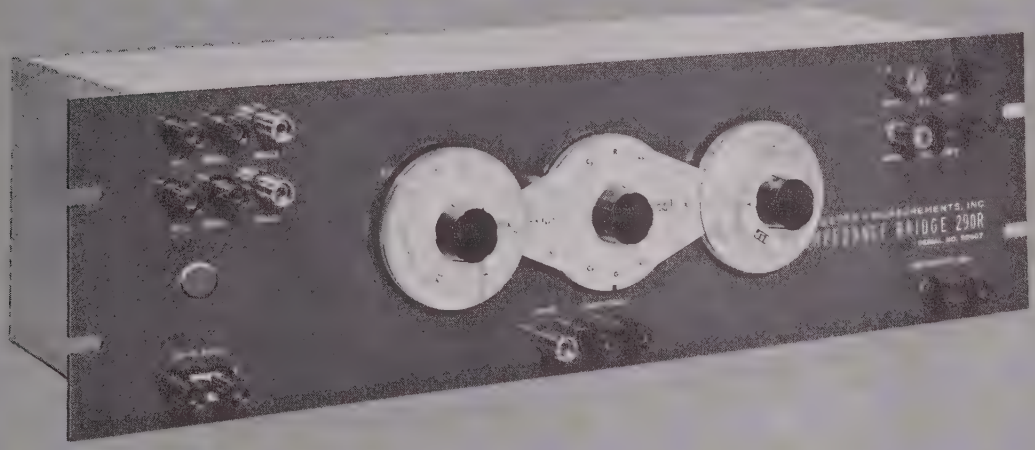
esi *Instruction Manual*

ELECTRO - MEASUREMENTS INC.
7524 S. W. MACADAM • PORTLAND, OREGON

BRIDGES
AND
ACCESSORIES

August 1958



Model 290-R

IMPEDANCE BRIDGE

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INSTRUCTION MANUAL

for

MODEL 290-R UNIVERSAL IMPEDANCE BRIDGE

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1. ACCESSORIES REQUIRED

1.1 For DC Measurements:

The ESI Model 840-R dc Generator and Detector is recommended for use with the Model 290-R bridge. If other dc generator and detector units are used, they should meet the following specifications:

1.1.1 DC Generator

Do not exceed 400 volts open circuit.

Limit power output to 1 watt or less

For example:

1.5 volts in series with 0.5 ohms or more
10 volts in series with 25 ohms or more
300 volts in series with 25K ohms or more

1.1.2 DC Detector

Desired characteristics:

Sensitivity: Approximately 0.03 microamperes per millimeter. Critically damped by a few kilohms.

1.2 For AC Measurements:

The ESI Model 860-R ac Generator and Detector unit is recommended for use with the Model 290-R bridge. If other ac generator and detector units are used, they should meet the following specifications:

1.2.1 AC Generator

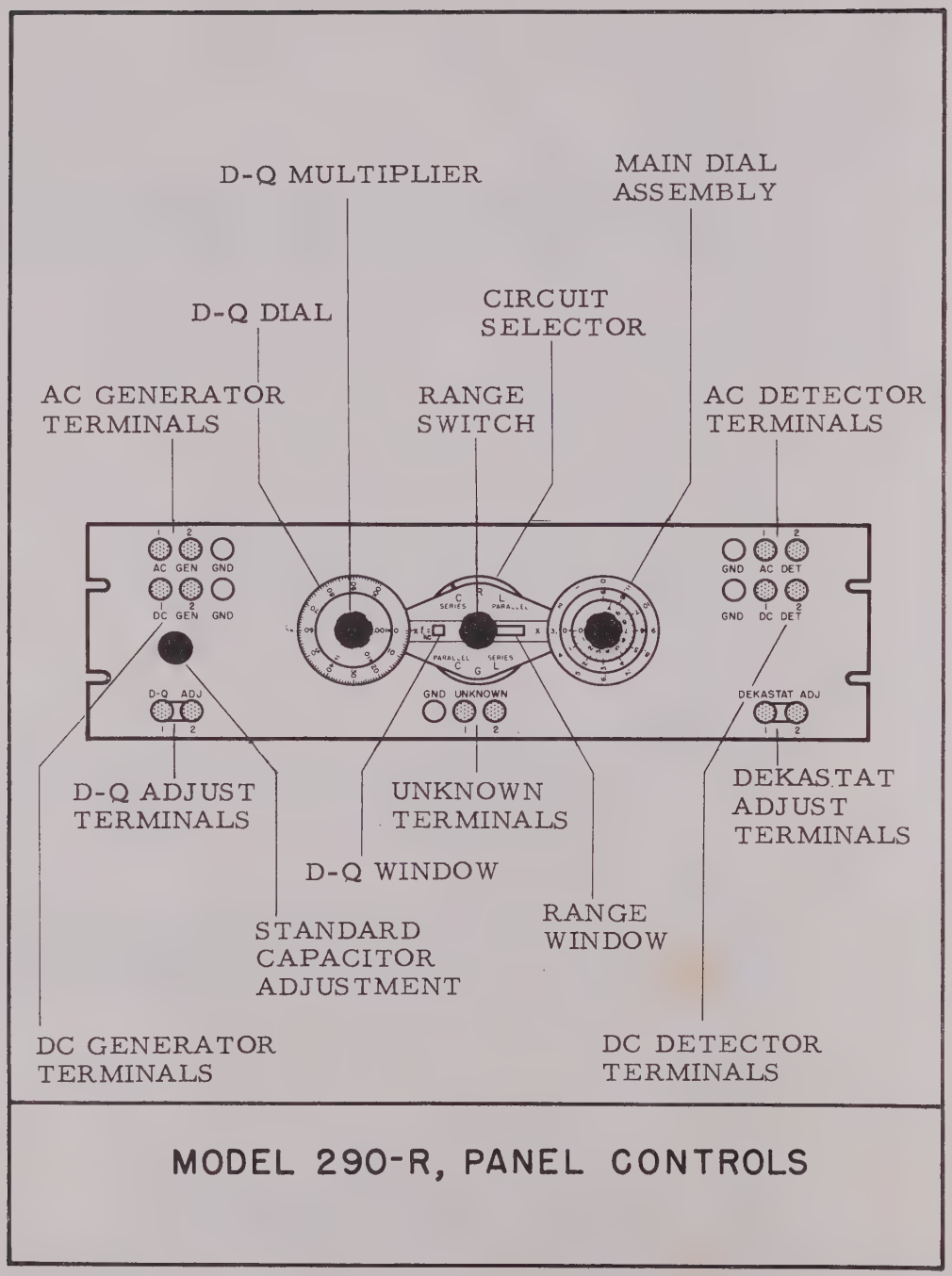
Desired characteristics:

Frequency Range: 0.1 kc to 10 kc
Output Voltage: 0 to 20 volts open circuit
Series Protective Resistor: 100 ohms or more

1.2.2 AC Detector

Desired characteristics:

Sensitivity: 20 microvolts
Input Impedance: 500K ohms
Harmonic Suppression: 20db by 2nd harmonic



MODEL 290-R, PANEL CONTROLS

2. CONTROLS

2.1 Circuit Selector: The large center dial selects the bridge circuit and connects the appropriate generator and detector.

Circuit		Measurement	Generator and Detector
1.	C_s	Series Capacitance	ac 860-R
2.	R^s	Resistance	dc 840-R
3.	L_p	Parallel Inductance	ac 860-R
4.	L^p_s	Series Inductance	ac 860-R
5.	G^s	Conductance	dc 840-R
6.	C_p	Parallel Capacitance	ac 860-R

The circuit in use is indicated by the mark at the edge of the selector switch. The electrical measurement unit is indicated in the right half of the right-hand window. For L or C measurements, the left-hand window shows whether the dissipation factor (D) or the storage factor (Q) is being measured.

2.2 Range Switch: The black center knob selects any of seven multipliers ranging from 10^{-4} to 100. The multiplier in use appears in the left half of the right-hand window.

2.3 Main Dial Assembly: The right-hand DEKASTAT dial reading times the range multiplier reading gives the value of resistance, conductance, inductance, or capacitance being measured.

2.4 D-Q Multiplier: The left-hand black knob selects the D-Q multiplier. The multiplying factor in use appears at the left of the D or Q value.

2.5 D-Q Dial: The reading of the large left-hand dial, times the D-Q multiplier reading, times the frequency in kilocycles gives the value of D or Q.

2.6 Unknown Terminals: The unknown component is connected to the two black terminals under the center dials. An adjacent metal ground terminal is provided for a shield connection.

2.7 Generator Terminals: The upper left-hand terminals are for connecting an external generator to the bridge. Separate terminals are provided for dc and ac connections. Ground terminals are provided for convenience.

2.8 Detector Terminals: The upper right-hand terminals are for connecting an external detector to the bridge. Separate terminals are provided for dc and ac connections. Ground terminals are provided for convenience.

2.9 D-Q Adjustment Terminals: The lower left-hand terminals are for attaching an external circuit element to the D-Q arm of the bridge for special measurements.

2.10 DEKASTAT Adjustment Terminals: The lower right-hand terminals are for attaching an external circuit element to the main dial DEKASTAT arm of the bridge for special measurements.

2.11 Standard Capacitor Adjustment: The left center hole cover conceals the adjusting screw for the standard capacitor. Setting this adjustment to give the correct bridge reading for an accurately known value of capacitance (0.1 μf recommended) assures a short term bridge accuracy rating improvement of 0.1% for all inductance and capacitance measurements.

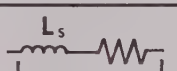
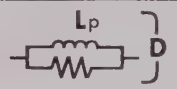
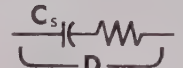
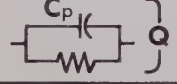
3. OPERATING INSTRUCTIONS

3.1 WHAT THE BRIDGE MEASURES

The ESI Model 290-R Impedance Bridge measures resistance, conductance, inductance, and capacitance. It also measures the dissipation factor (D) and the storage factor (Q) of inductors and capacitors.

Resistance and conductance measurements are usually made with direct current because of the increased accuracy and the lack of hum pickup and stray capacitance effects. Resistance and conductance measurements can be made using ac, but they may require external reactance compensation.

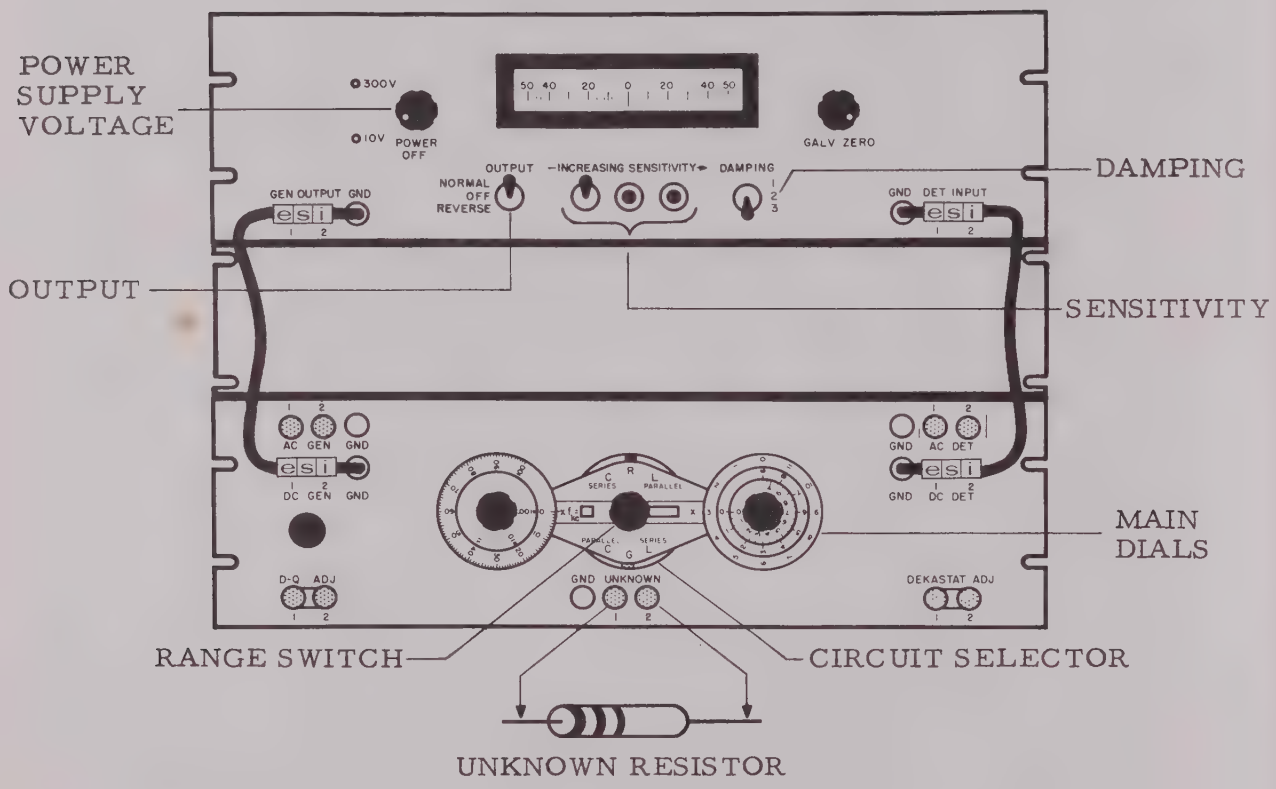
Inductance and capacitance measurements are made in terms of a simple two-element circuit with the same impedance as the unknown. The bridge dials read the values of this equivalent circuit. To achieve highest measurement accuracy, an equivalent parallel circuit is used for high Q inductors and high D capacitors. An equivalent series circuit is used for low D capacitors and low Q inductors.

Selector Switch Setting	Equivalent Circuit	Magnitude		Frequency	D and Q			Recommended Generator and Detector
		Range	Smallest Step On Lowest Range			Range	Smallest Step On Lowest Range	
R		0 to 1200 kilohms	10^{-7} kilohms (0.1 milliohm)	dc *				ESI 840-R
G		0 to 1200 millimhos	10^{-7} millimhos (100μμmho)	dc *				ESI 840-R
L Series		0 to 1200 henries	10^{-7} henries (0.1 μh)	0.1 kc 1 kc 10 kc	Q	0 to 1.05 0 to 10.5 0 to 105	0.0001 0.001 0.01	ESI 860-R
L Parallel		0 to 1200 henries	10^{-7} henries (0.1 μh)	0.1 kc 1 kc 10 kc	D	0 to 1.05 0 to 10.5 0 to 105	0.0001 0.001 0.01	ESI 860-R
C Series		0 to 1200 microfarads	10^{-7} microfarads (0.1 μμf)	0.1 kc 1 kc 10 kc	D	0 to 1.05 0 to 10.5 0 to 105	0.0001 0.001 0.01	ESI 860-R
C Parallel		0 to 1200 microfarads	10^{-7} microfarads (0.1 μμf)	0.1 kc 1 kc 10 kc	Q	0 to 1.05 0 to 10.5 0 to 105	0.0001 0.001 0.01	ESI 860-R

* Resistance and conductance measurements can be made using ac, but they may require external reactance compensation.

3.2 RESISTORS

3.2.1 MEASURING RESISTORS *the esi way*



CONNECT DC GENERATOR AND DETECTOR	Connect the external dc generator and detector to the dc terminals. They will be connected to the correct bridge circuits by the circuit selector.

WARNING: Limit the generator output to one watt maximum. The ESI Model 840-R dc generator and detector has this protective feature built in.

CONNECT RESISTOR TO UNKNOWN TERMINALS	Make good contact with the terminals.
SET CIRCUIT SELECTOR TO <u>R</u> OR <u>G</u>	If between 0.83 ohms and 1.2 megohms, measure either RESISTANCE or CONDUCTANCE. If less than 0.83 ohms (>1.2 mho), measure RESISTANCE. If greater than 1.2 megohms (<0.83 micromhos), measure CONDUCTANCE.

$$R \text{ in kilohms} = \frac{1}{G \text{ in millimhos}}$$

3.2.1 MEASURING RESISTORS (Cont.)

SET POWER SUPPLY VOLTAGE AND DETECTOR SENSITIVITY

(See above WARNING)

When using the ESI 840-R generator and detector, the voltage settings shown below will give maximum sensitivity.

WHEN USING THE 840-R

SET THE OUTPUT SWITCH TO "NORMAL"

SET THE LEFT HAND SENSITIVITY SWITCH UP

SET THE DAMPING SWITCH TO "3"

840-R Switch Position	Resistance	Conductance
10 V	0 to 0.1 kilohms	10 to 1,200 millimho
300 V	0.1 to 1,200 kilohms	0 to 10 millimho

SET MAIN DIAL TO READ 3.00

This setting makes it easier to find the correct range.

SET RANGE SWITCH FOR MINIMUM DETECTOR SIGNAL

This sets the range so that the value can be found with maximum resolution on the main dial.

ADJUST MAIN DIAL FOR NULL

The detector sensitivity can be increased as the null is approached. If the Galvanometer is sluggish try damping position 1 or 2. The ESI Model 840-R generator and detector cannot be damaged by normal bridge use at any setting. Be careful to avoid damage if any other detector is used.

IF THE MAIN DIAL READING IS LESS THAN 1.200, USE THE NEXT LOWER RANGE AND READJUST MAIN DIAL FOR NULL

This takes advantage of the increased resolution near full scale of the dial.

3.2.2 THINGS TO WATCH OUT FOR

3.2.2.1 HIGH RESISTANCE MEASUREMENTS

Care must be taken to avoid leakage resistance across the unit being measured. If an electronic null detector is being used it may be affected by ac hum picked up by the leads.

3.2.2.2 LOW RESISTANCE MEASUREMENTS

On the low resistance ranges the lead resistance in the unknown arm becomes significant. A correction for this resistance can be made as follows:

1. Short the test leads together at the point that they are to be connected to the unknown resistor and measure this "ZERO RESISTANCE".

2. Connect the test leads to the unknown resistor and measure the "RESISTANCE READING".

3. The "RESISTANCE VALUE" of the unknown resistor is then the "RESISTANCE READING" minus the "ZERO RESISTANCE".

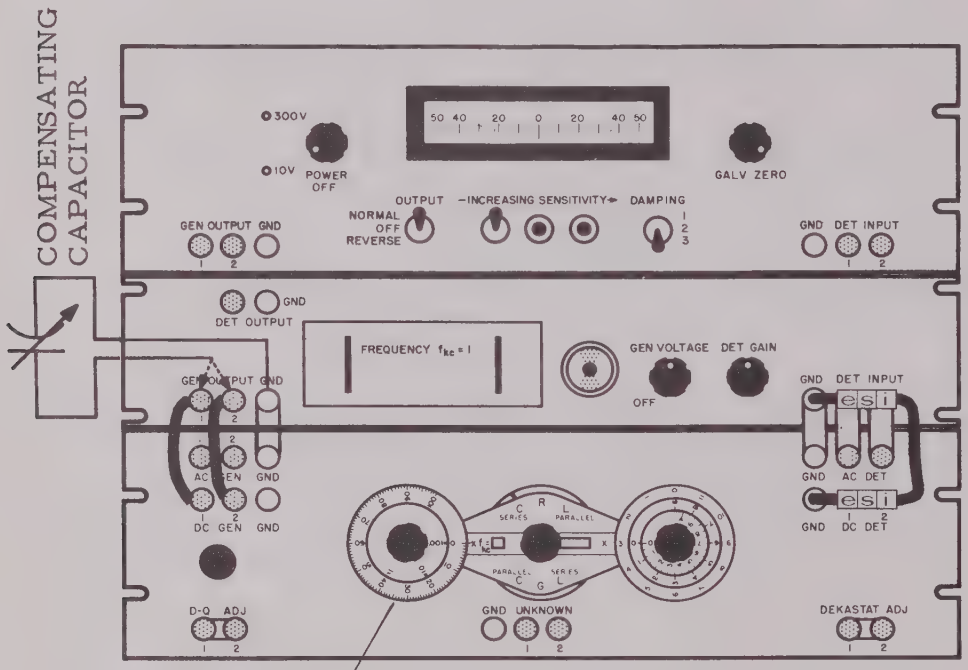
4. If the unknown resistance is to be connected directly to the terminals, the "ZERO RESISTANCE" reading can be taken by connecting a piece of heavy copper wire between the unknown resistance terminals. (#14 AWG copper wire has a resistance of about 0.00025 ohm/inch.)

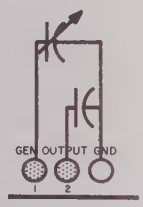
Sometimes thermal voltages are generated at connections and these can lead to erroneous balances of the bridge. If this condition is suspected, balance the bridge and then set the output switch to "reverse". If this results in a different galvanometer reading, change the main dial DEKASTAT® setting until the galvanometer reads the same for both output polarities. This cancels the effect of the thermal voltages.

3.2.3 MEASURING AC RESISTANCE *the esi way*

For greatest accuracy resistors should always be measured with dc. The accuracy of ac measurement will be 0.3% for one kilocycle and below over the range from one ohm to one megohm.

The indicated connections for the phase correction capacitor compensate for series inductance or parallel capacitance. It is impossible to seperate the correction for the unknown from that for the rest of the bridge circuit. If large reactances are involved the circuit should be measured as a capacitance or inductance and the resistance calculated.





NOTE:
If the phase correction is small it may be convenient to connect a fixed capacitor to one terminal and a variable one to the other.

REMOVE THE AC GENERATOR CONNECTING STRAPS	The ac detector straps need not be removed
CONNECT THE BRIDGE DC GENERATOR AND DETECTOR TERMINALS TO THE AC GENERATOR AND DETECTOR	Short lengths of open-wire leads for the generator will minimize errors
SET THE BRIDGE ON THE R OR G RANGE	This connects the desired bridge circuit
TRY TO BALANCE THE BRIDGE AS WITH DC	Usually the eye will not completely open, thus indicating uncompensated phase shift

CONNECT A VARIABLE CAPACITOR FROM GROUND TO ONE OF THE GENERATOR TERMINALS AND TRY TO OBTAIN A NULL WITH IT AND THE MAIN DIALS.

Connecting the capacitor from ground to either generator terminal permits compensation for some of the possible circuits of the unknown.

IF A NULL CANNOT BE REACHED, CONNECT THE VARIABLE CAPACITOR BETWEEN THE OTHER GENERATOR TERMINAL AND GROUND. A NULL SHOULD BE OBTAINABLE WITH ONE CONNECTION OR THE OTHER.

This permits balance over the remaining possible circuit combinations.

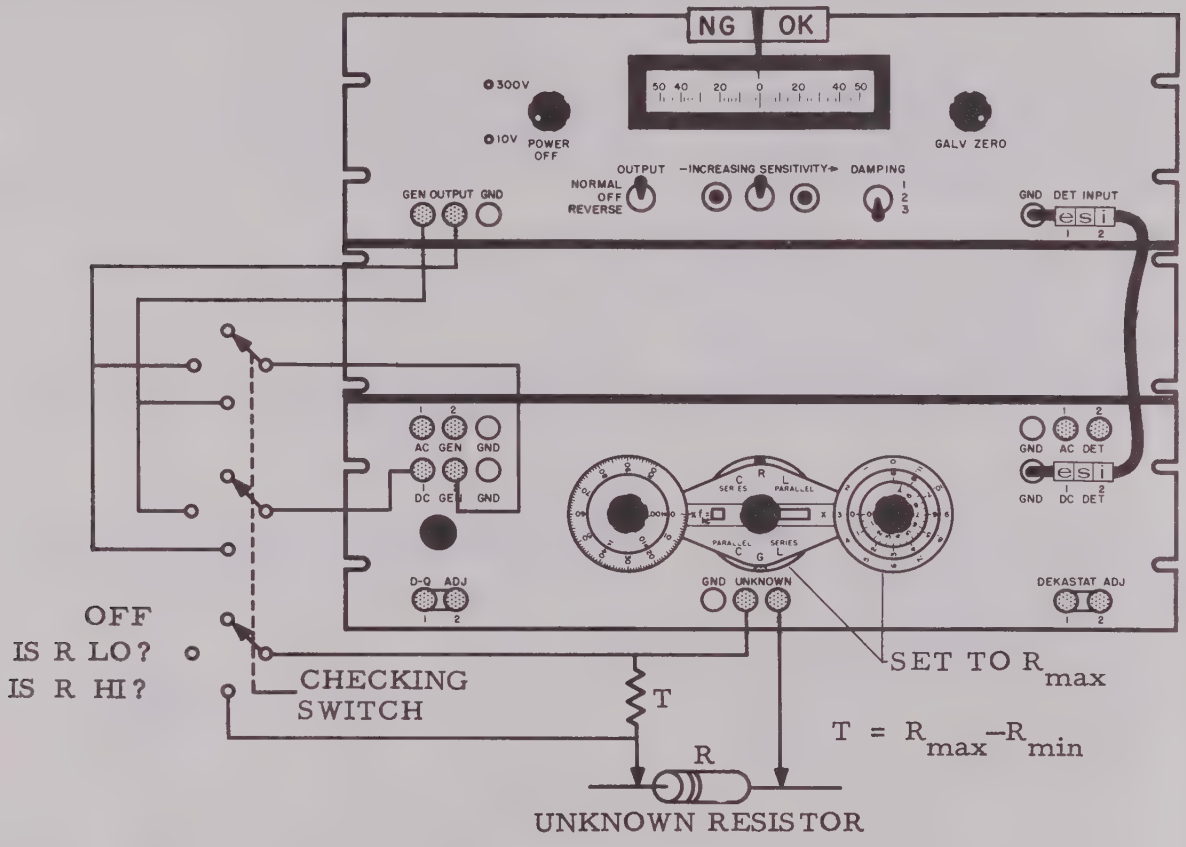
If a non linear element is being measured by ac a null balance may not be possible because the bridge will not be in balance at all parts of the cycle.

THE "RESISTANCE" VALUE AS READ WILL BE CORRECT FOR EQUIVALENT CIRCUITS CONSISTING OF A RESISTOR AND CAPACITOR IN PARALLEL OR A RESISTOR AND INDUCTOR IN SERIES.

R and G accuracy will be 0.3% or better for resistors between 1 ohm and 1 megohm at a frequency of 1 kc or less.

3.2.4 RESISTANCE LIMITS CHECKING *the esi way*

For rapidly checking resistance values between two tolerance limits.



3.2.4.1 BASIC INSTRUCTIONS

SET THE CIRCUIT SELECTOR TO R OR G. SET THE RANGE SWITCH AND MAIN DIAL DEKASTAT® TO THE UPPER RESISTANCE LIMIT.	These settings will allow checking both upper and lower limits.
CONNECT THE CIRCUIT AS SHOWN.	The battery reversal permits using the same direction of GALVANOMETER deflection for OK with both the upper and lower limit.
ATTACH THE PROBES TO THE UNKNOWN RESISTOR.	This completes the bridge circuit.
CHECK THE ZERO POSITION OF THE GALVANOMETER POINTER.	The zero position may be adjusted by the GALVANOMETER ZERO SET dial.

3.2.4.1 RESISTANCE LIMITS CHECKING (Cont.)

FIND THE OPTIMUM SENSITIVITY SETTING BY TRIAL.	The sensitivity buttons may be left in the lock position without endangering the GALVANOMETER.
SET THE CHECKING SWITCH TO "IS R LO?".	If the GALVANOMETER deflects to the right the unknown resistor is above the lower tolerance limit.
SET THE CHECKING SWITCH TO "IS R HI?".	If the GALVANOMETER deflects to the right the unknown resistor is below the upper tolerance limit.

NOTE: If the resistance tolerance is given as $\pm\Delta\%$, the value of T will be $\frac{R2\Delta}{100}$ and R_{max} will be $(1 + \frac{\Delta}{100})$ R.

3.2.4.2 CHECKING HIGH RESISTANCE:

When checking high resistances the 300 volt supply should be used. The off position of the checking switch has been provided to remove this voltage from the bridge while changing resistors.

3.2.4.3 CHECKING LOW RESISTANCE:

When checking low resistances the probe resistance R_o must be taken into account. It can be measured by shorting the probes. The bridge dials should be set to read $R_{max} + R_o$.

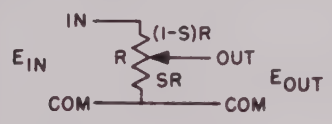
RESISTANCE LIMITS CHECKING

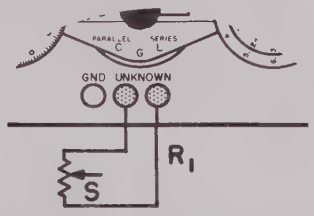
IF
$R_{MIN} < R < R_{MAX}$
AND IF
$T = R_{MAX} - R_{MIN}$
THEN
$(R_{MEAS}) < R_{MAX}$ Only if $R < R_{MAX}$
$(R_{MEAS} + T) > R_{MAX}$ Only if $R > R_{MIN}$

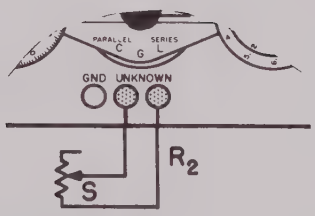
IF
$R(1+\Delta) = R_{MAX}$
$R(1-\Delta) = R_{MIN}$
THEN
$T = R2\Delta$

3.2.5 VOLTAGE DIVIDER CHECKING *the esi way*

3.2.5.1 SIMPLE TAPPED RESISTOR



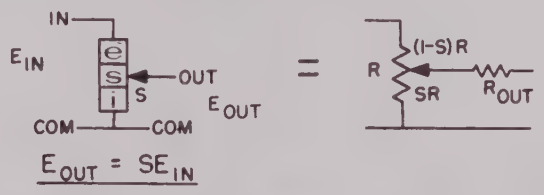


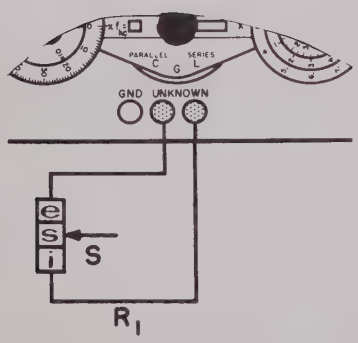


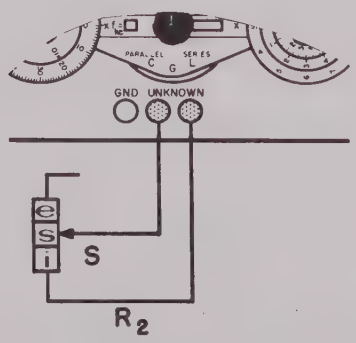
1. Follow the instructions for RESISTANCE measurement (3.2).
2. Measure R_1 between the input and common terminals.
3. Measure R_2 between the output and common terminals.
4. Calculate the divider setting S.

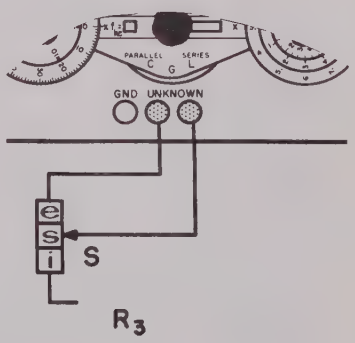
$$S = \frac{R_2}{R_1}$$

3.2.5.2 KELVIN VARLEY and other voltage divider types which may have equivalent resistance in the output lead.







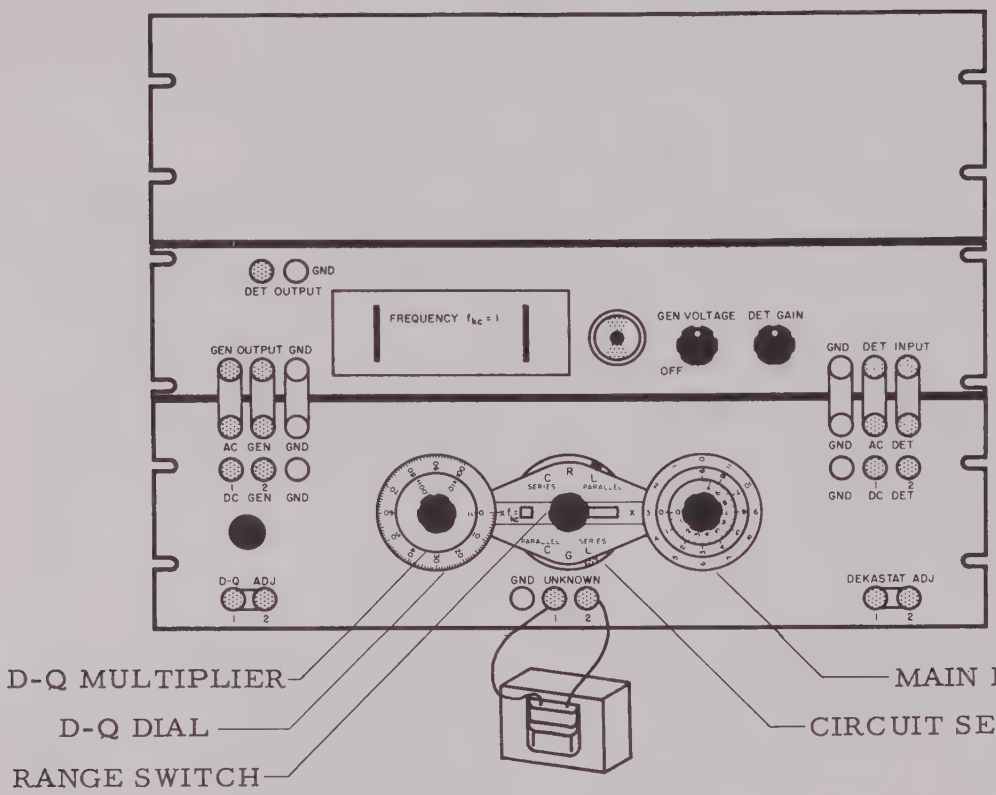


1. Follow the instructions for RESISTANCE measurement (3.2)
2. Measure R_1 between the input and common terminals.
3. Measure R_2 between the output and common terminals.
4. Measure R_3 between the input and output terminals.
5. Calculate the divider setting S.

$$S = \frac{1}{2} + \frac{R_3 - R_2}{2R_1}$$

3.3 INDUCTORS

3.3.1 MEASURING INDUCTORS *the esi way*



OPERATING INSTRUCTIONS

CONNECT AC GENERATOR AND DETECTOR

Connect the external generator and detector to the ac terminals. They will then be connected to the correct bridge circuits by the circuit selector.

> WARNING: Limit the generator output to one watt maximum. The ESI Model 860-R ac generator and detector has this protective feature built in.

CONNECT INDUCTOR TO UNKNOWN TERMINALS

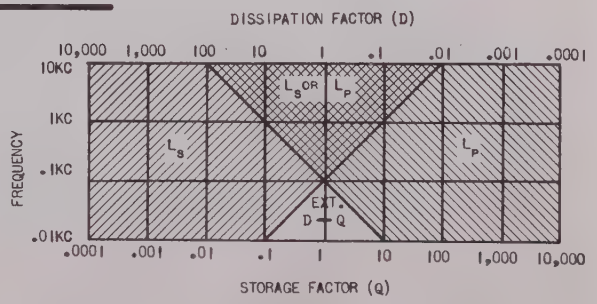
Make good contact with the terminals.

SET CIRCUIT SELECTOR TO L_p OR L_s

At 1 kc:

Use L_p for Q greater than 0.1

Use L_s for Q lower than 10



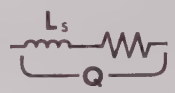
SET GENERATOR VOLTAGE AND DETECTOR GAIN (See above WARNING)	For 860-R generator-detector unit, set generator voltage control and detector gain control with dots up.
SET MAIN DIAL TO READ 3.000 SET D-Q MULTIPLIER TO .1x SET D-Q DIAL TO: 0, IF BRIDGE MEASURES D, OR 100, IF BRIDGE MEASURES Q	These settings make it easier to find the correct range.
SET RANGE SWITCH FOR MINIMUM DETECTOR SIGNAL	This sets the range so that the value can be found with maximum resolution on the main dial.
ADJUST MAIN DIAL AND D-Q DIAL ALTERNATELY FOR NULL	The broad sensitivity of the ESI 860-R detector unit makes sensitivity adjustment unnecessary for most measurements.
IF THE MAIN DIAL READING IS LESS THAN 1.200, USE NEXT LOWER RANGE AND READJUST MAIN DIAL FOR NULL IF D-Q DIAL READING IS LESS THAN 10, USE NEXT LOWER SETTING OF D-Q MULTIPLIER AND READJUST D-Q DIAL FOR NULL	This takes advantage of the increased resolution near full scale of the dials.

SEE NEXT PAGE

3.3.2 SERIES AND PARALLEL INDUCTANCE

The bridge measures a simple equivalent circuit for the impedance connected to its terminals. This equivalent circuit consists of either an inductance and resistance connected in series or a different inductance and resistance connected in parallel. The phase and magnitude of the resulting impedance are identical for both circuits. For values of Q less than 100 the series and parallel inductances differ measurably (by more than 0.01%).

WHEN THE BRIDGE MEASURES SERIES INDUCTANCE, L_s:



L_s = (range switch setting) x (main dial reading)

Q = (D-Q multiplier setting) x (D-Q dial reading) x (f_{kc})

$D = \frac{1}{Q}$

$R_s = \frac{1}{Q} \times 2\pi f L_s$

$Z = 2\pi f L_s (\frac{1}{Q} + j)$

Q and D in per unit
R_s in kilohms
f in kc
L_s in henrys
$j = \sqrt{-1}$
Z in kilohms

To calculate the equivalent parallel circuit:

The Q of the equivalent parallel circuit always equals the Q of the equivalent series circuit. The same is true of D.

$L_p = (1 + \frac{1}{Q^2}) \times L_s$

$R_p = Q \times 2\pi f L_p$

WHEN THE BRIDGE MEASURES PARALLEL INDUCTANCE, L_p:

L_p = (range switch setting) x (main dial reading)

D = (D-Q multiplier setting) x (D-Q dial reading) x (f_{kc})

$Q = \frac{1}{D}$

$R_p = \frac{1}{D} \times 2\pi f L_p$

$Z = \frac{2\pi f L_p (D+j)}{D^2 + 1}$

D and Q in per unit
R_p in kilohms
f in kc
L_p in henrys
$j = \sqrt{-1}$
Z in kilohms

To calculate the equivalent series circuit:

The D of the equivalent series circuit always equals the D of the equivalent parallel circuit. The same is true of Q.

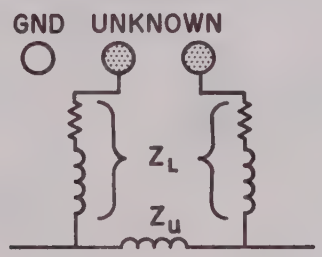
$L_s = \frac{1}{1 + D^2} \times L_p$

$R_s = D \times 2\pi f L_s$

3.3.3 THINGS TO WATCH OUT FOR

3.3.3.1 LOW INDUCTANCE MEASUREMENTS

The bridge measures the total impedance connected to its terminals. Both the unknown inductor and its leads contribute to this impedance. The leads have some resistance and inductance, which affect the value read from the bridge.



$$Z_{measured} = Z_u + Z_L$$

Z_u - Impedance of unknown inductor

Z_L - Impedance of leads

For greatest accuracy, minimize the lead impedance. Short heavy leads will reduce the resistance. Closely spaced twisted leads will reduce the inductance and the pickup of stray fields.

3.3.3.2 HIGH INDUCTANCE MEASUREMENTS

In making high inductance measurements, there are two things to watch out for:

1. Be careful to avoid hum pickup.
2. Keep the stray capacitance to a minimum.

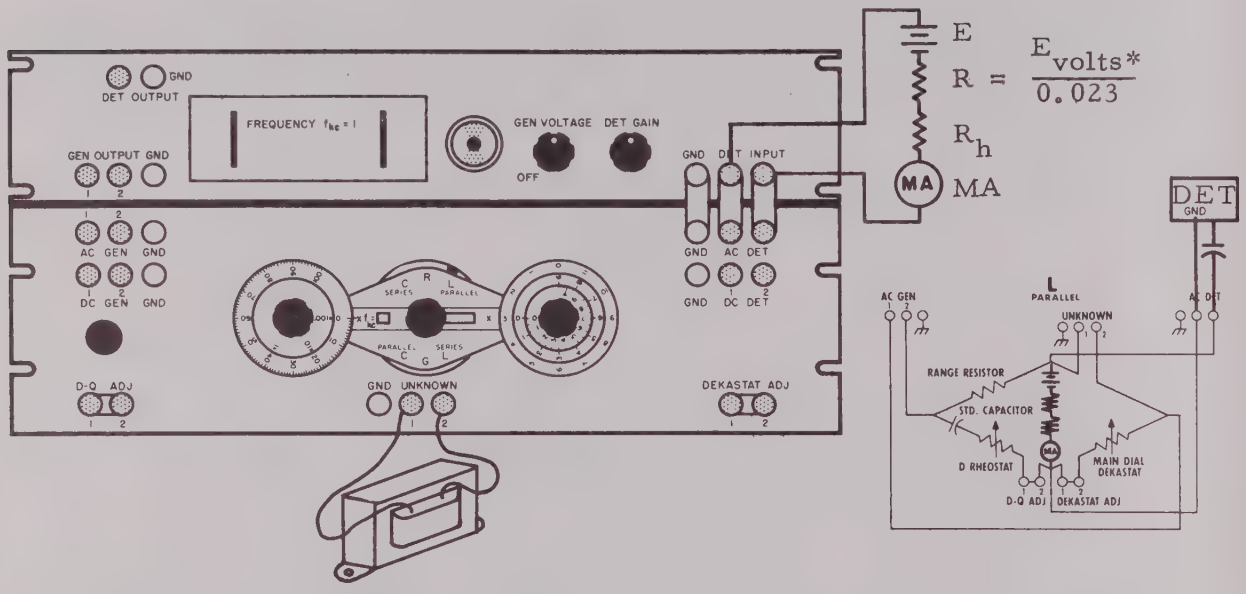
To minimize both effects keep your hands as far as possible from the inductor measured.

Keep the leads as short and direct as possible. If extended leads are necessary, the lead from the center terminal should be shielded. See section 3.4.6 "Extended Leads".

Care should be taken to avoid coupling stray magnetic fields into the inductor being measured.

3.3.4 INDUCTANCE MEASUREMENT WITH DC

3.3.4.1 For parallel inductance measurements with superimposed dc:



CONNECT IN SERIES

E - VOLTAGE SOURCE

R - CURRENT LIMITING RESISTOR

$$R = \frac{E_{volts}*}{0.023}$$

R_h - CURRENT ADJUSTING RHEOSTAT

MA - CURRENT MONITORING METER

THEN CONNECT THESE ACROSS THE DETECTOR

The detector input should have an isolating capacitor. This capacitor is built into the Model 860-R Generator - Detector.

ADJUST THE DC CURRENT AS REQUIRED

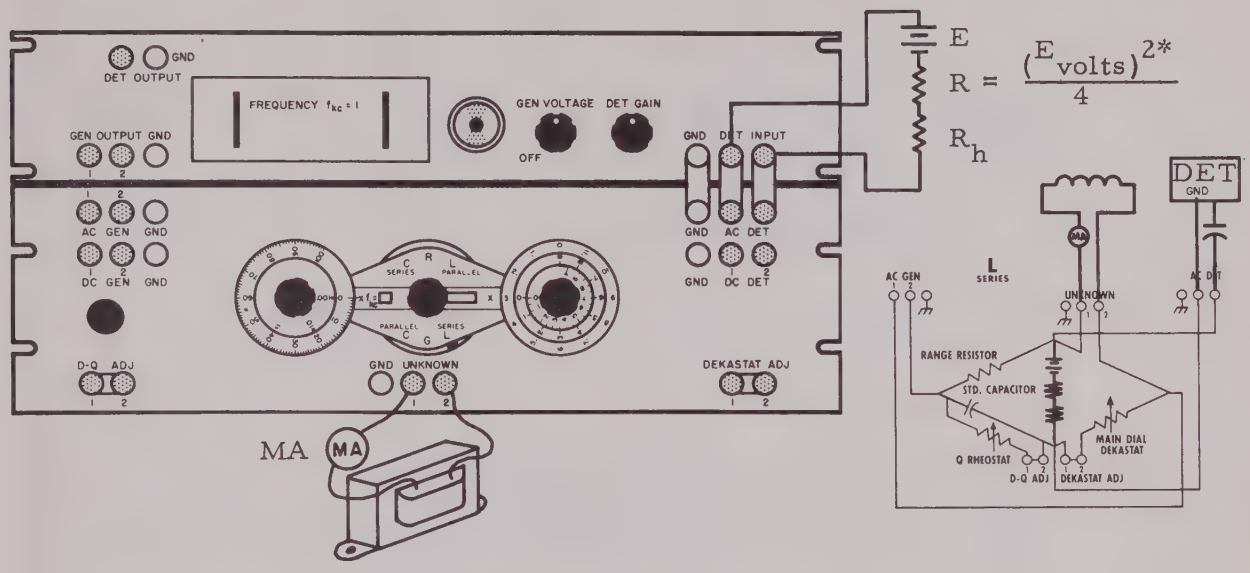
The current will vary with the setting of the main dial.

MEASURE THE INDUCTANCE

See Section 3.3

*This limits the current through the main dial DEKASTAT to a safe value (23 ma).

3.3.4.2 For series inductance measurements with superimposed dc:



CONNECT IN SERIES

E - VOLTAGE SOURCE

R - CURRENT LIMITING RESISTOR

$$R = \frac{(E_{volts})^2}{4} \quad *$$

R_h - CURRENT ADJUSTING RHEOSTAT

The detector input should have an isolating capacitor. This capacitor is built into the Model 860-R Generator - Detector.

THEN CONNECT THESE ACROSS THE DETECTOR

CONNECT THE METER MA IN SERIES WITH THE UNKNOWN INDUCTOR

The impedance of most meters is low enough so that it will not cause a great error in the measurement.

ADJUST THE DC CURRENT AS REQUIRED

The current will vary with the setting of the main dial.

MEASURE THE INDUCTANCE

See Section 3.3

*This limits the dc power which can be supplied to the bridge to one watt to protect all of the bridge circuit. With care these current and voltage limits can be extended somewhat. The voltage and current ratings of all of the bridge circuit elements is given in Section 5. These values should never be exceeded.

3.3.5 VOLTAGE MEASUREMENT

To measure the ac voltage applied to the unknown inductor:

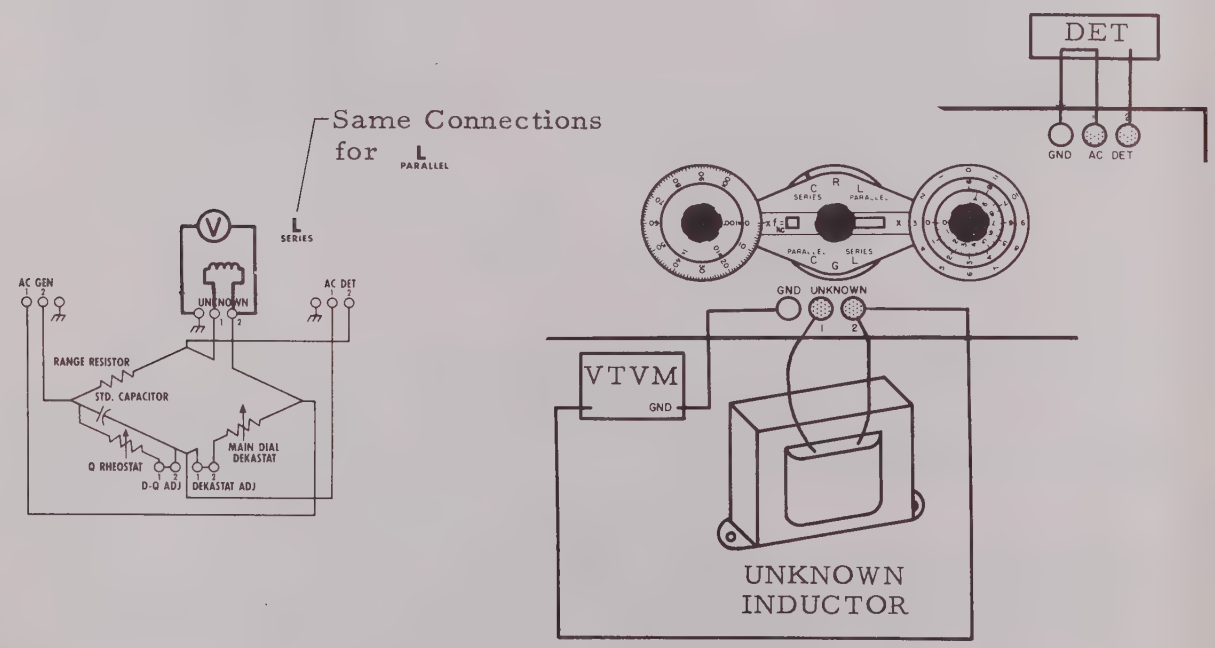
Connect ac detector terminal No. 1 to ground. This is done internally in the 860-R Generator-Detector. To prevent ground loops do not make any additional connections.

Connect the ground terminal of a high impedance ac voltmeter to the ground terminal of the bridge.

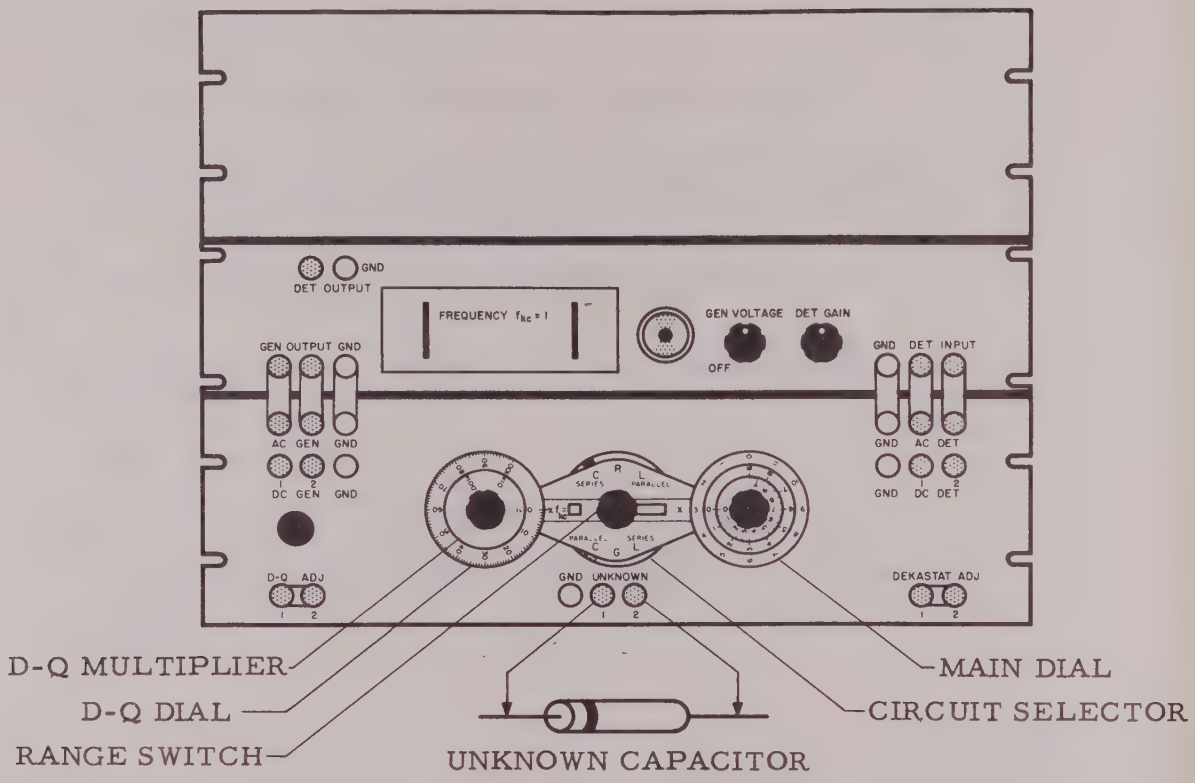
Connect the input terminal of the voltmeter to the right-hand terminal of the bridge.

Balance the bridge.

Read the voltmeter. With the bridge balanced, this voltage is equal to the ac voltage across the unknown inductor, but the inductor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the meter is connected.



3.4.1 MEASURING CAPACITORS *the esi way*



OPERATING INSTRUCTIONS

CONNECT AC GENERATOR AND DETECTOR

WARNING: Limit the generator output to one watt maximum. The ESI Model 860-R ac generator and detector has this protective feature built in.

Connect the external generator and detector to the ac terminals. They will then be connected to the correct bridge circuits by the circuit selector.

CONNECT CAPACITOR TO UN-UNKNOWN TERMINALS

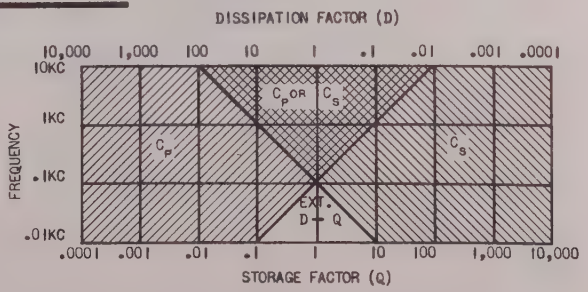
To minimize stray capacitance to ground, connect the outside foil to the left hand terminal.

SET THE CIRCUIT SELECTOR TO C_s OR C_p

At 1 kc:

Use C_p for D greater than 0.1

Use C_s for D lower than 10



Range of D and Q covered by C_s and C_p circuits.

3.4.1 MEASURING CAPACITORS (Cont.)

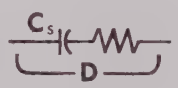
SET GENERATOR VOLTAGE AND DETECTOR GAIN (See Above WARNING)	For the 860-R ac generator-detector unit, set generator voltage control and detector gain control with dots up.
SET MAIN DIAL TO READ 3.000 SET D-Q MULTIPLIER TO .1x SET D-Q DIAL TO 0, IF BRIDGE MEASURES D, OR 100, IF BRIDGE MEASURES Q	These settings make it easier to find the correct range.
SET THE RANGE SWITCH FOR MINIMUM DETECTOR SIGNAL	This sets the range so that the value can be found with maximum resolution on the main dial.
ADJUST MAIN DIAL AND D-Q DIAL ALTERNATELY FOR NULL	The broad sensitivity range of the ESI 860-R detector unit makes sensitivity adjustment unnecessary for most measurements.
IF THE MAIN DIAL READING IS LESS THAN 1.200, USE NEXT LOWER RANGE AND READJUST MAIN DIAL FOR NULL IF D-Q DIAL READING IS LESS THAN 10, USE NEXT LOWER SETTING OF D-Q MULTIPLIER AND READJUST D-Q DIAL FOR NULL	This takes advantage of the increased resolution near full scale of the dials.

SEE NEXT PAGE

3.4.2 SERIES AND PARALLEL CAPACITANCE

The bridge measures a simple equivalent circuit for the impedance connected to its terminals. This equivalent circuit consists of either a capacitance and resistance connected in series or a different capacitance and resistance connected in parallel. The phase and magnitude of the resulting impedance are identical for both circuits. For values of D greater than 0.01 the series and parallel capacitances differ measurably (by more than 0.01%).

WHEN THE BRIDGE MEASURES SERIES CAPACITANCE, C_s:



C_s = (range switch setting) x (main dial reading)

D = (D-Q multiplier setting) x (D-Q dial reading) x (f_{kc})

$Q = \frac{1}{D}$

$R_s = \frac{D}{2\pi f C_s}$

$Z = \frac{D - j}{2\pi f C_s}$

D and Q in per unit
R_s in kilohms
f in kc
C_s in microfarads
$j = \sqrt{-1}$
Z in kilohms

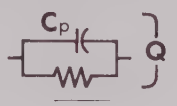
To calculate the equivalent parallel circuit:

The D of the equivalent parallel circuit always equals the D of the equivalent series circuit. The same is true of Q.

$C_p = \frac{C_s}{(1 + D^2)}$

$R_p = \frac{1}{D} \times \frac{1}{2\pi f C_p}$

WHEN THE BRIDGE MEASURES PARALLEL CAPACITANCE, C_p:



C_p = (range switch setting) x (main dial reading)

Q = (D-Q multiplier) x (D-Q dial reading) x (f_{kc})

$D = \frac{1}{Q}$

$R_p = \frac{Q}{2\pi f C_p}$

$Z = \frac{\frac{1}{Q} - j}{2\pi f C_p (1 + \frac{1}{Q^2})}$

Q and D in per unit
R_p in kilohms
f in kc
C_p in microfarads
$j = \sqrt{-1}$
Z in kilohms

To calculate the equivalent series circuit:

The Q of the equivalent series circuit always equals the Q of the equivalent parallel circuit. The same is true of D.

$C_s = (1 + \frac{1}{Q^2}) \times C_p$

$R_s = \frac{1}{Q} \times \frac{1}{2\pi f C_s}$

3.4.3 THINGS TO WATCH OUT FOR

3.4.3.1 LOW CAPACITANCE MEASUREMENTS

In making low capacitance measurements, there are two things to watch out for:

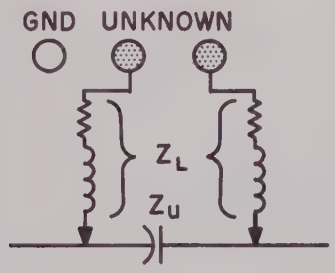
1. Be careful to avoid hum pickup.
2. Keep the stray capacitance to a minimum.

To minimize both effects, keep your hands as far as possible from the capacitor being measured.

Keep the leads as short and direct as possible. If extended leads are necessary, the lead from the center terminal should be shielded. See section 3.4.6, "Extended Leads."

3.4.3.2 HIGH CAPACITANCE MEASUREMENTS

The bridge measures the total impedance connected to its terminals. Both the unknown capacitor and its leads contribute to this impedance. The leads have some resistance and inductance, which affect the value read from the bridge.



$$Z_{measured} = Z_u + Z_L$$

Z_u = Impedance of unknown capacitor

Z_L = Impedance of leads

For the greatest accuracy, minimize the lead impedance. Short heavy leads will reduce the resistance. Closely spaced twisted leads will reduce the inductance and the pickup of stray fields.

3.4.4 POLARIZING VOLTAGE

3.4.4.1 When to use a Polarizing Voltage

Some capacitors need a polarizing voltage. For example, electrolytic and tantalytic units can be damaged by the reverse polarity half-cycle of the test frequency. Even if the capacitors are not damaged, erroneous readings may result.

3.4.4.2 When a Polarizing Voltage is Not Necessary

A polarizing voltage is not always needed in these measurements. If the ac voltage is kept at a very low value, the capacitor will not be damaged, and the readings will be reasonably accurate.

Because of the high sensitivity of the Model 291 bridge, accurate measurements can be made with a very low oscillator voltage. When operating with a low oscillator voltage, be sure that the detector sensitivity is maximum.

3.4.4.3 How to Supply a Polarizing Voltage

The C series bridge must be used for measurements with a polarizing voltage.

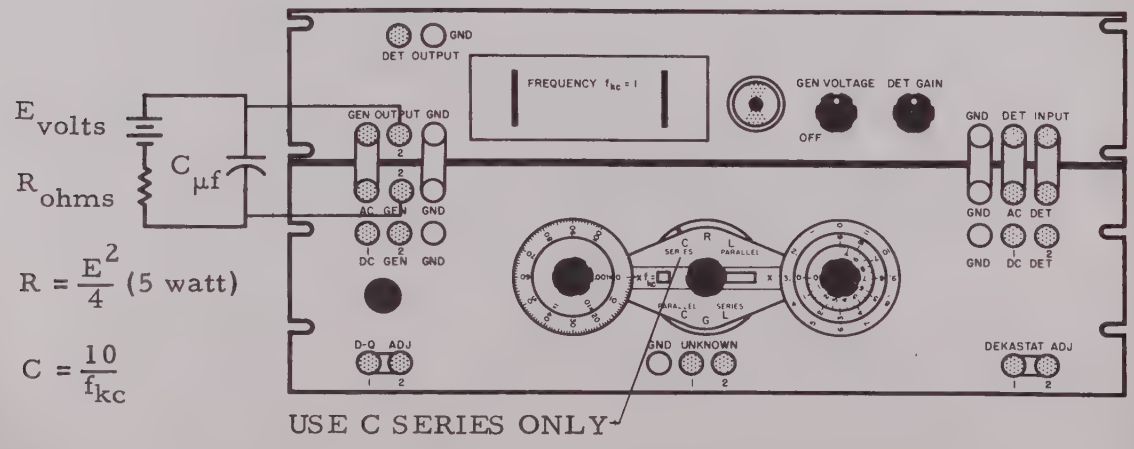
The dc supply may be inserted in series with the generator leads.

Keep the dc source well insulated, and keep the capacitance to ground as small as possible. Use of a battery is recommended.

The maximum recommended polarizing voltage is 300 v.

The polarizing voltage should be in series with the ac generator. Direct current is then blocked from flowing through the bridge by the unknown capacitor in one arm, and the standard capacitor in the other arm.

The dc source should be by-passed by a capacitor. A current limiting resistor will protect the bridge from damage in case of short circuits. The necessary resistance is supplied internally in the 840-R dc generator and detector.



3.4.5 VOLTAGE MEASUREMENT

To measure the ac voltage applied to the unknown capacitor:

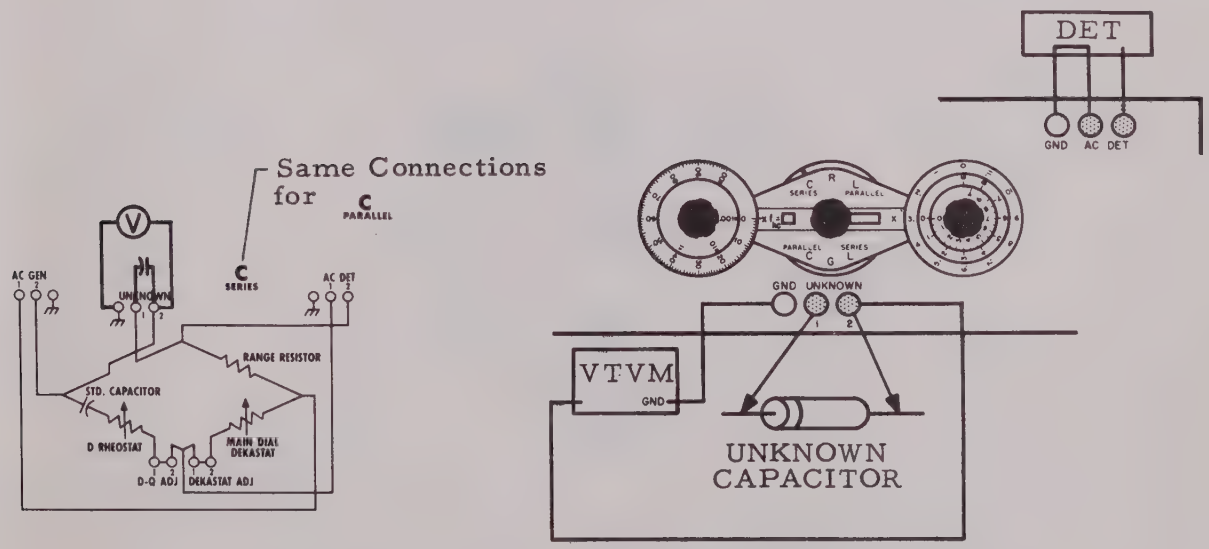
Connect ac detector terminal No. 1 to ground. This is done internally in the 860-R Generator-Detector. To prevent ground loops do not make any additional connections.

Connect the ground terminal of a high impedance ac voltmeter to the ground terminal of the bridge.

Connect the input terminal of the voltmeter to the right-hand terminal of the bridge.

Balance the bridge.

Read the voltmeter. With the bridge balanced, this voltage is equal to the ac voltage across the unknown capacitor, but the capacitor has not been loaded by the voltmeter. The bridge readings, however, may be incorrect while the meter is connected.



3.4.6 EXTENDED LEADS

Sometimes it is necessary to use extended leads. This can be done easily without causing error in the measurement.

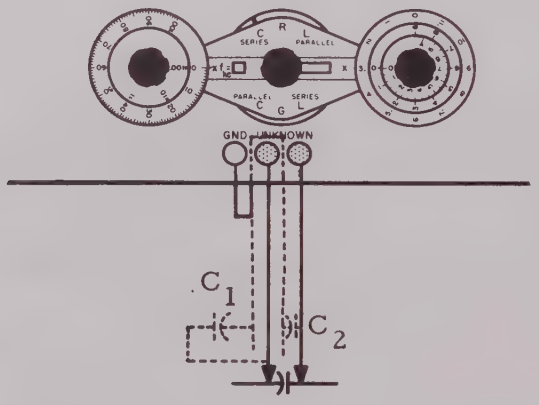
Connect a shielded lead to the center terminal.

Connect the shield of this lead to the shield terminal of the bridge.

Connect an ordinary clip lead to the right-hand terminal.

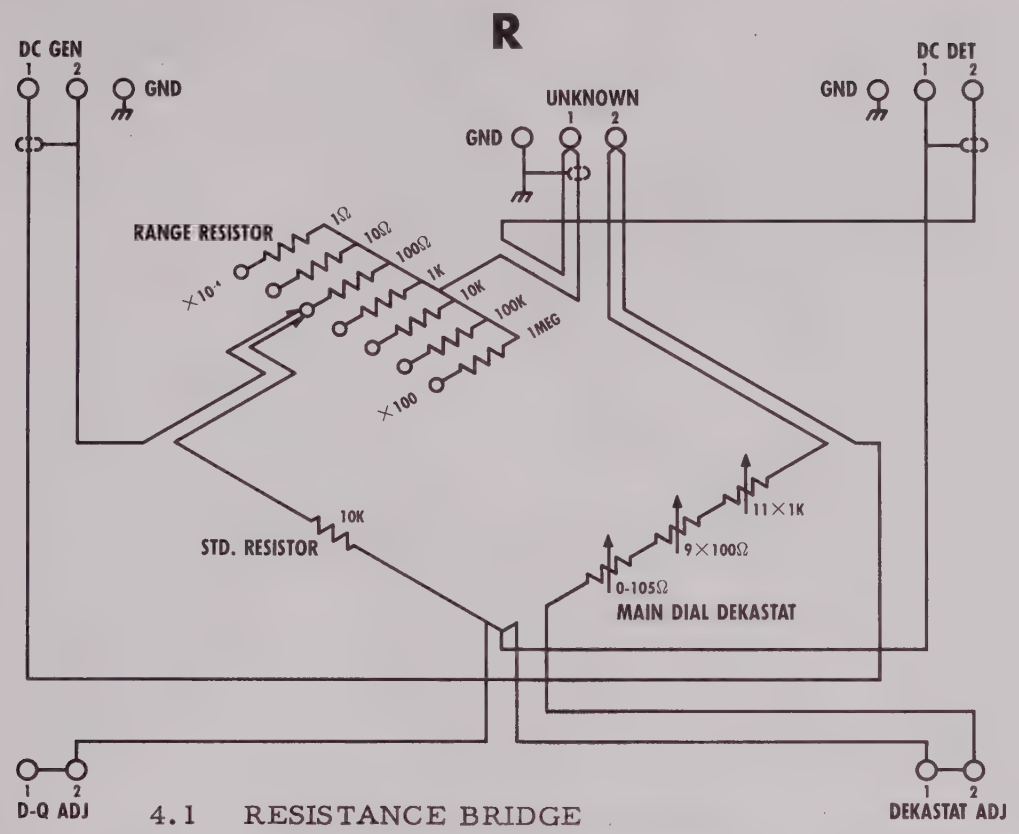
The capacitance between the shield and the center conductor is now across the detector. This keeps it from causing any error. If this stray capacitance is greater than 500 μμf, it may reduce the detector sensitivity.

The stray capacitance from the unshielded lead to ground is across the standard capacitance arm of the bridge. As the standard capacitor is 100,000 μμf, the stray capacitance will not cause significant errors unless it exceeds a few 10's of μμf.

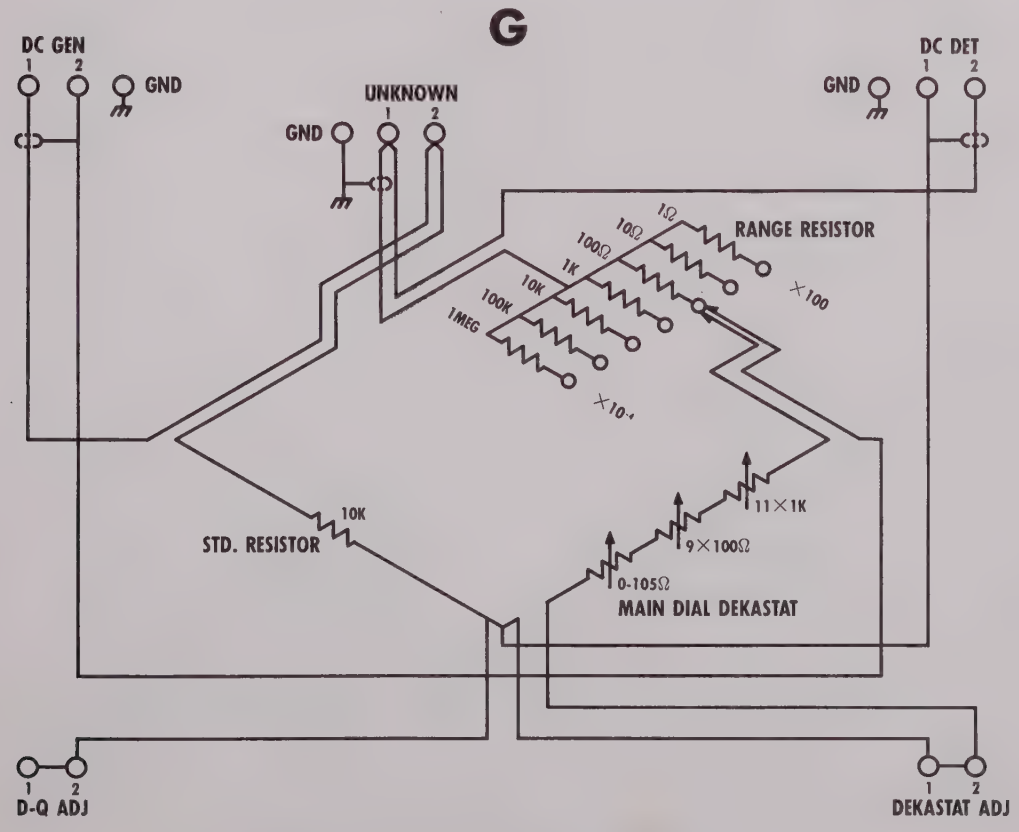


C_1: Capacitance from center conductor to ground

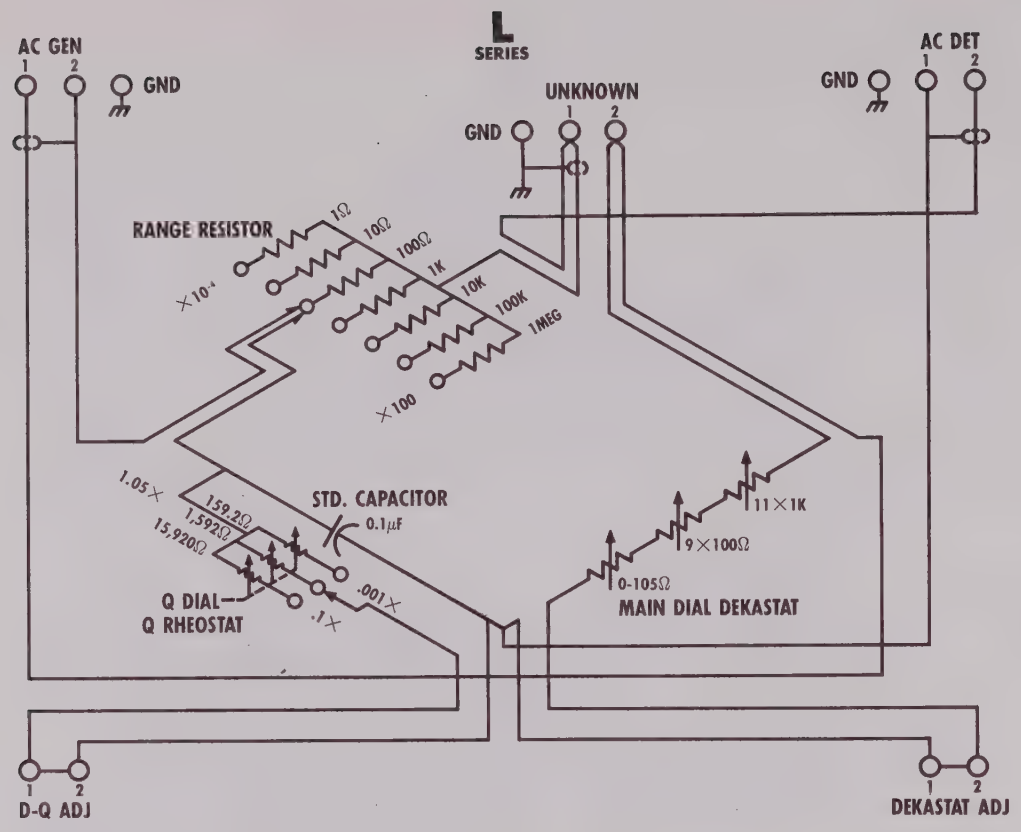
C_2: Capacitance from unshielded conductor to ground



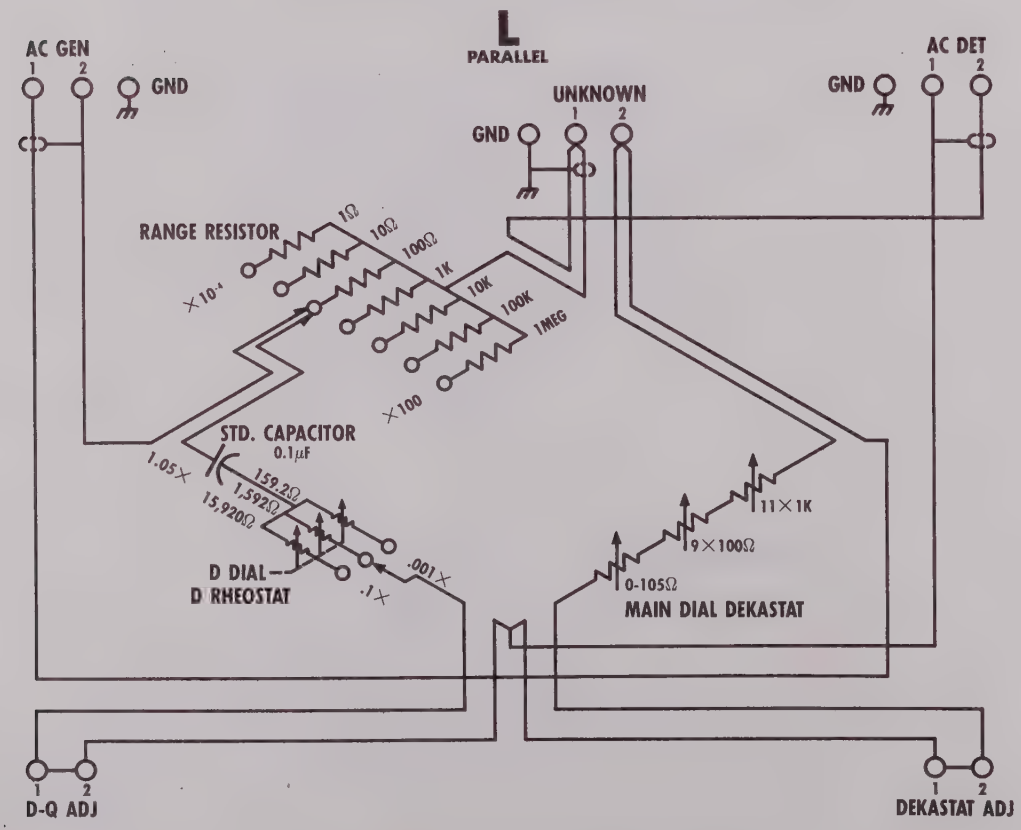
4.1 RESISTANCE BRIDGE



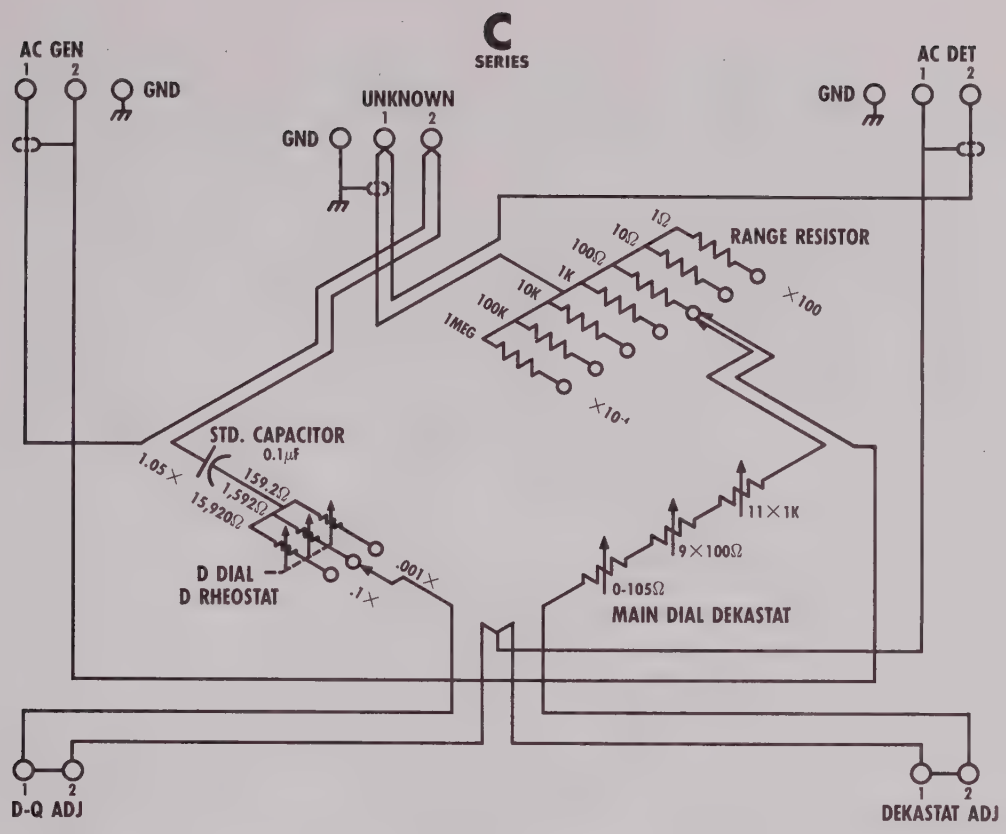
4.2 CONDUCTANCE BRIDGE



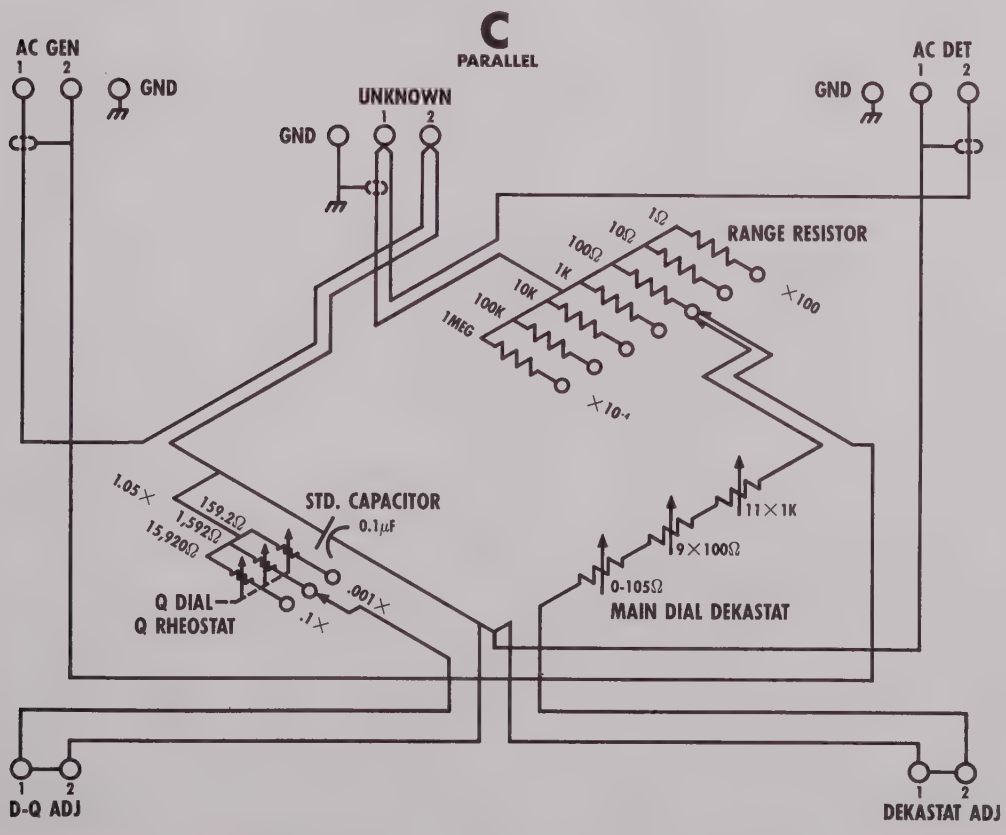
4.3 SERIES INDUCTANCE BRIDGE



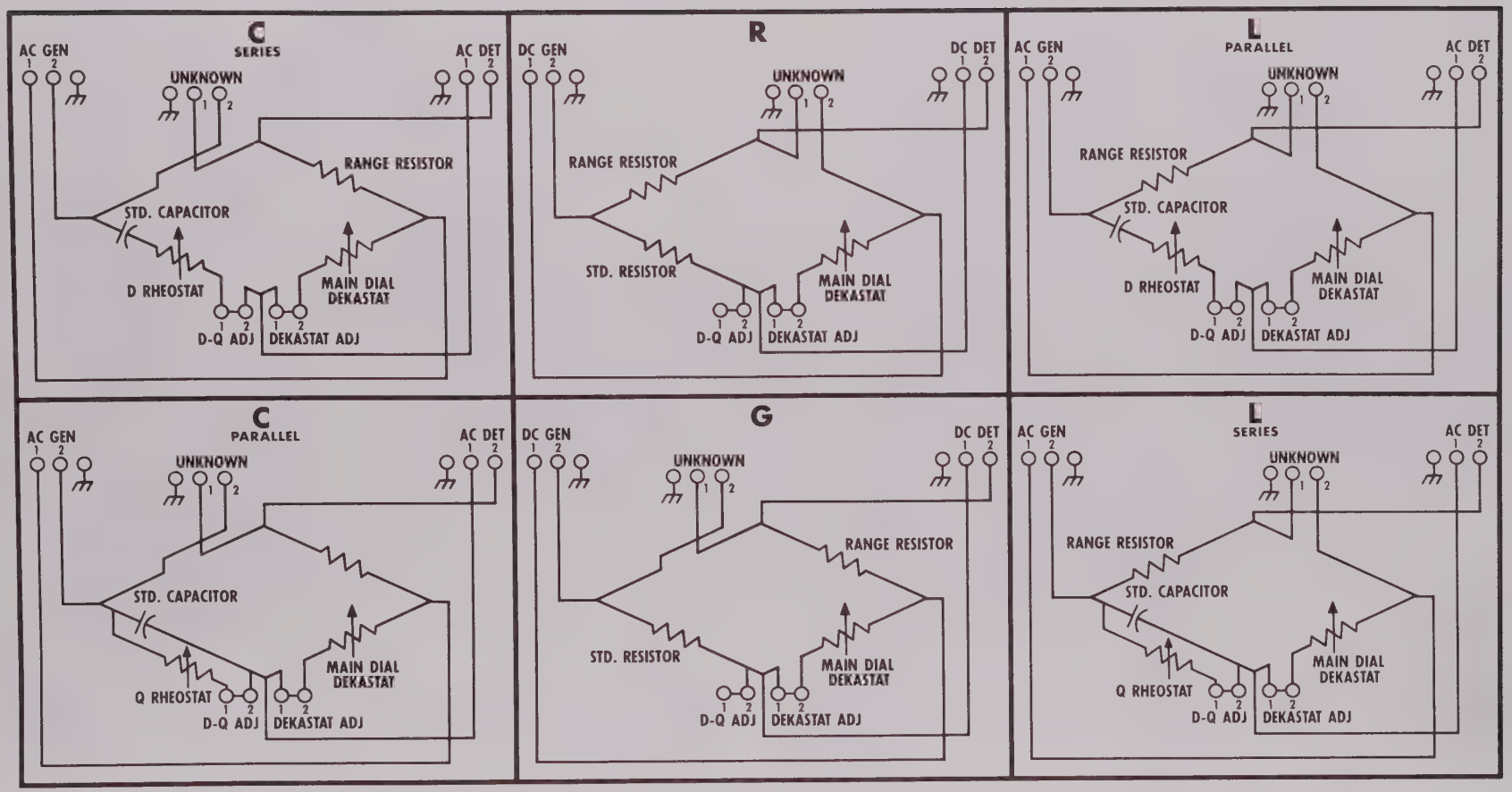
4.4 PARALLEL INDUCTANCE BRIDGE



4.5 SERIES CAPACITANCE BRIDGE



4.6 PARALLEL CAPACITANCE BRIDGE


C
SERIES
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AC DET
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STD. CAPACITOR
D RHEOSTAT
MAIN DIAL
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MAIN DIAL
DEKASTAT
D-Q ADJ
DEKASTAT ADJ

5. BRIDGE ELEMENT VOLTAGE AND CURRENT LIMITS

RANGE RESISTORS

Safe Power limited to 1/2 watt per resistor

Resistance in Ohms	Voltage in Volts Max	Current in Milliamperes Max
1	0.71	710.00
10	2.30	230.00
100	7.10	71.00
1,000	23.00	23.00
10,000	71.00	7.10
100,000	230.00	2.30
1,000,000	250.00	0.25

D-Q RHEOSTATS

Safe power limited to 7 watts into total resistance

Resistance in Kilohms	Maximum Resistance in Ohms	Voltage in Volts Max	Current in Milliamperes Max
D-Q reading x 0.01592	166	35	210
D-Q reading x 0.1592	1,670	110	68
D-Q reading x 1.5920	16,750	350	21

STANDARD RESISTOR

Safe power limited to 1/2 watt

Resistance in Ohms	Voltage in Volts Max	Current in Milliamperes Max
10,000	71	7.1

6. CONVENIENT AUDIO FREQUENCY UNITS

For measurement and calculation in the audio frequency range the conventional electrical units are often inconvenient. A consistent set of units can be chosen so that the numerical values commonly encountered will be more practical while at the same time the equations used in calculations will not require any troublesome conversion constants. If either set of units listed below is followed consistently, the equations used for calculations will be unaltered. For example, E = IR holds true equally well with E in volts, I in amperes, and R in ohms; or with E in volts, I in milliamperes and R in kilohms. The 291 dials read directly in these "convenient" units.

Function	Conventional Units	Convenient Audio Frequency Units
ω	radian/sec = $2\pi f_{cps}$	kiloradian/sec = $2\pi f_{kc}$
f	cps	kc
t	second	millisecond
C	farad	microfarad
Z, R and X	ohm	kilohm
L	henry	henry
I	ampere	milliamp
E	volt	volt
P	watt	milliwatt
Q and D	per unit ratio	per unit ratio

esi *Instruction Manual*

ELECTRO - MEASUREMENTS INC.
7524 S. W. MACADAM • PORTLAND, OREGON

BRIDGES
AND
ACCESSORIES

August 1958

Model 840-R

DC GENERATOR-DETECTOR

excellent scientific instruments

esi

INSTRUCTION MANUAL

for

MODEL 840-R DC GENERATOR AND DETECTOR

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1. Controls (See attached Catalog Sheet C-13 for Specifications)
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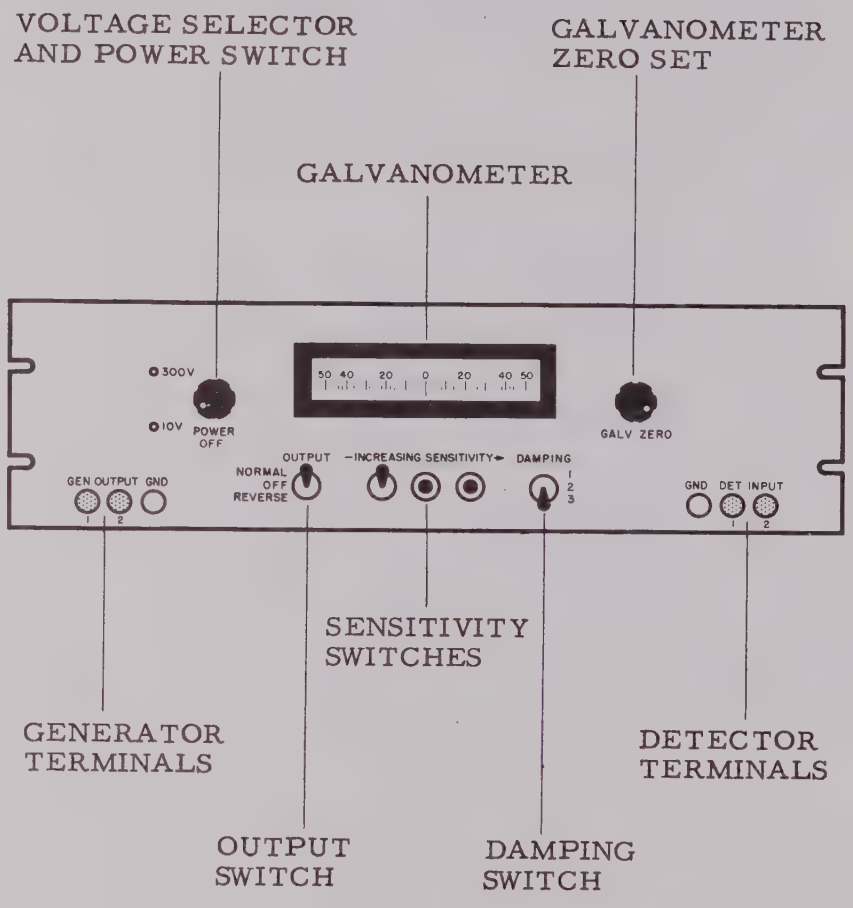
     - 1.1.1 Voltage Selector
     - 1.1.2 Output Switch
     - 1.1.3 Generator Terminals
   - 1.2 Detector
     - 1.2.1 Galvanometer
     - 1.2.2 Galvanometer Zero Set
     - 1.2.3 Sensitivity Switches
     - 1.2.4 Damping Switch
     - 1.2.5 Detector Terminals
2. Using the 840-R
3. Circuit Diagram



MODEL 840-R DC GENERATOR AND DETECTOR
PANEL CONTROLS

1. CONTROLS

1.1 GENERATOR

1.1.1 Voltage Selector: The left hand control knob is used to select the generator voltage and operate the power switch. The voltage in use is indicated by the pilot light at the appropriate switch position.

1.1.2 Output Switch: The left hand switch connects the generator to the output terminals. The polarity is reversed by changing the switch position.

1.1.3 Generator Terminals: The left hand terminals are used for connecting the generator to an external circuit. Both generator terminals are well insulated from the panel. A ground terminal is provided for convenience.

1.2 DETECTOR

1.2.1 Galvanometer: The large window is the display for the light beam galvanometer.

1.2.2 Galvanometer Zero Set: The right hand control knob adjusts the zero setting of the galvanometer.

1.2.3 Sensitivity Switches: The three switches below the galvanometer window set the galvanometer sensitivity. Each switch has an upper "lock-in" position, a center "off" position, and a lower "momentary-contact" position. Sensitivity increases from left to right.

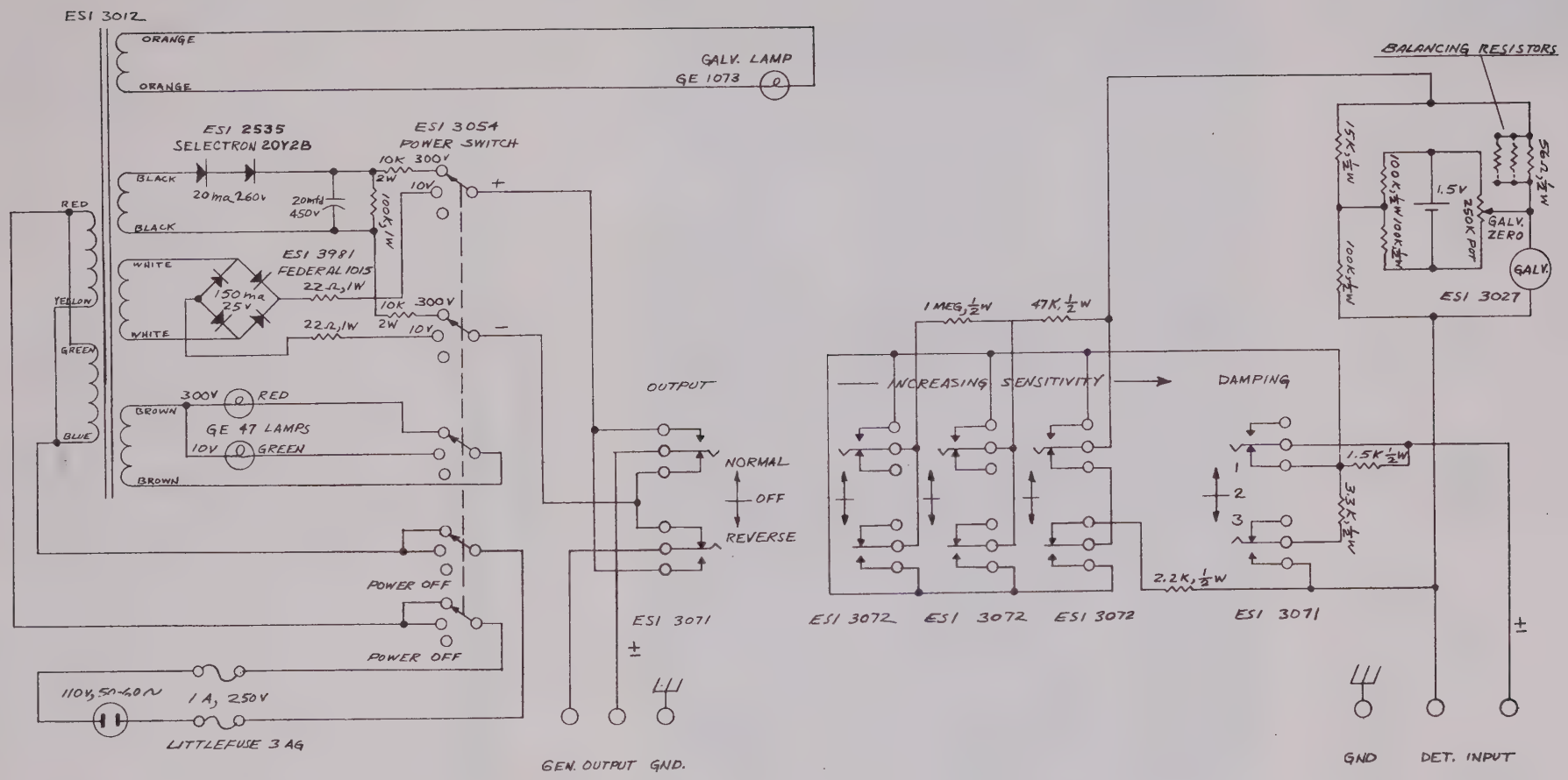
1.2.4 Damping Switch: The right hand switch selects from three damping circuits to provide optimum damping with any external resistance.

Position 1	provides series damping for use with low resistance circuits.
Position 2	provides a direct connection to the galvanometer for use with external circuits of approximately 2,000 ohms.
Position 3	provides shunt damping for use with high resistance circuits.

1.2.5 Detector Terminals: The right hand terminals are used for connecting the detector to an external circuit. Both detector terminals are well insulated from the panel. A ground terminal is provided for convenience.

2. USING THE 840-R DC GENERATOR DETECTOR *the esi way*

WARNING: Before touching generator terminals, or any part of circuit, always set output switch to OFF.	This will remove the voltage from the generator terminals so that connections can be made safely.
SET ALL LEVER SWITCHES TO CENTER "OFF" POSITION.	This disconnects the generator and detector from the terminals on the panel.
CONNECT GENERATOR OUTPUT AND DETECTOR INPUT TO BRIDGE	Note warning above.
CHECK GALVANOMETER ZERO	Adjust if necessary.
SET GENERATOR VOLTAGE TO 10 VOLTS	This turns on the galvanometer light beam and energizes the 10 volt power supply.
SET DAMPING SWITCH TO POSITION 3	This assures proper functioning of the sensitivity switches.
SET OUTPUT SWITCH TO "NORMAL"	This connects the generator terminals in the normal polarity.
TURN ON LOWEST SENSITIVITY SWITCH	Switch may be pressed down for momentary contact, or up for lock-in contact.
BALANCE BRIDGE, TURNING ON HIGHER SENSITIVITY SWITCHES AS NULL IS APPROACHED	Lower sensitivity switches can be left on if desired.
IF GALVANOMETER RESPONSE IS SLUGGISH WHEN HIGHEST SENSITIVITY SWITCH IS ON, CHANGE DAMPING SWITCH TO POSITION 1 OR 2	When highest sensitivity switch is on, position 2 of damping switch will give maximum sensitivity. If response is still sluggish, position 1 will improve response time, but may decrease sensitivity.
IF SENSITIVITY IS LOW, TRY INCREASING OUTPUT VOLTAGE TO 300 VOLTS	This supplies more power to high resistance circuits.
WARNING: This 300 volts may appear on any terminal of the generator or bridge. Use caution!	
BEFORE MAKING ANY CIRCUIT CHANGES, RETURN SWITCHES TO: OUTPUT------OFF SENSITIVITY--OFF	These settings will protect the bridge and the operator.



3. 840-R DC GENERATOR DETECTOR CIRCUIT DIAGRAM

esi *Instruction Manual*

BRIDGES
AND
ACCESSORIES

ELECTRO - MEASUREMENTS INC.
7524 S. W. MACADAM • PORTLAND, OREGON

August 1958

Model 860-R
AC GENERATOR-DETECTOR

excellent scientific instruments

esi

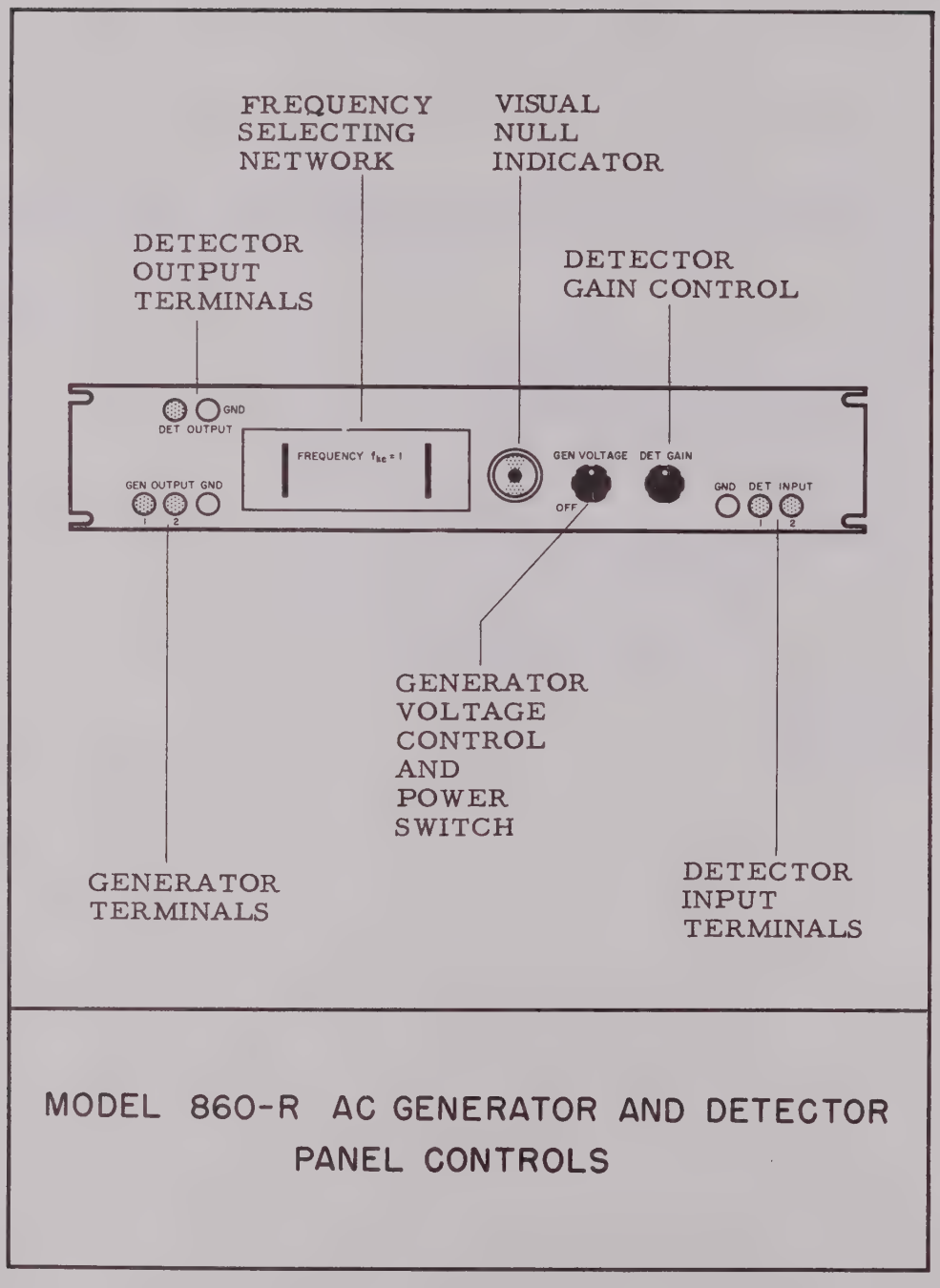
INSTRUCTION MANUAL

for

MODEL 860-R AC GENERATOR AND DETECTOR

TABLE OF CONTENTS (See attached catalog sheet C-13 for Specifications)

1. Controls
   - 1.1 Generator
     - 1.1.1 Generator Voltage Control
     - 1.1.2 Frequency Selecting Network
     - 1.1.3 Generator Terminals
   - 1.2 Detector
     - 1.2.1 Detector Gain Control
     - 1.2.2 Visual Null Indicator
     - 1.2.3 Detector Input Terminals
     - 1.2.4 Detector Output Terminals
2. Using the 860-R
3. Circuit Diagram



MODEL 860-R AC GENERATOR AND DETECTOR PANEL CONTROLS

1. CONTROLS

1.1 GENERATOR

1.1.1 Generator Voltage Control: The left hand knob controls the output voltage of the generator and operates the external power switch.

1.1.2 Frequency Selecting Network: The plug-in unit determines the operating frequency of both the generator and detector.

1.1.3 Generator Terminals: The lower left hand terminals are for connecting the generator to the bridge circuit. Both generator terminals are insulated from, and have low capacitance to, ground. A ground terminal is provided for shield connections.

1.2 DETECTOR

1.2.1 Detector Gain Control: The right hand knob varies the sensitivity of the lower half of the null indicator.

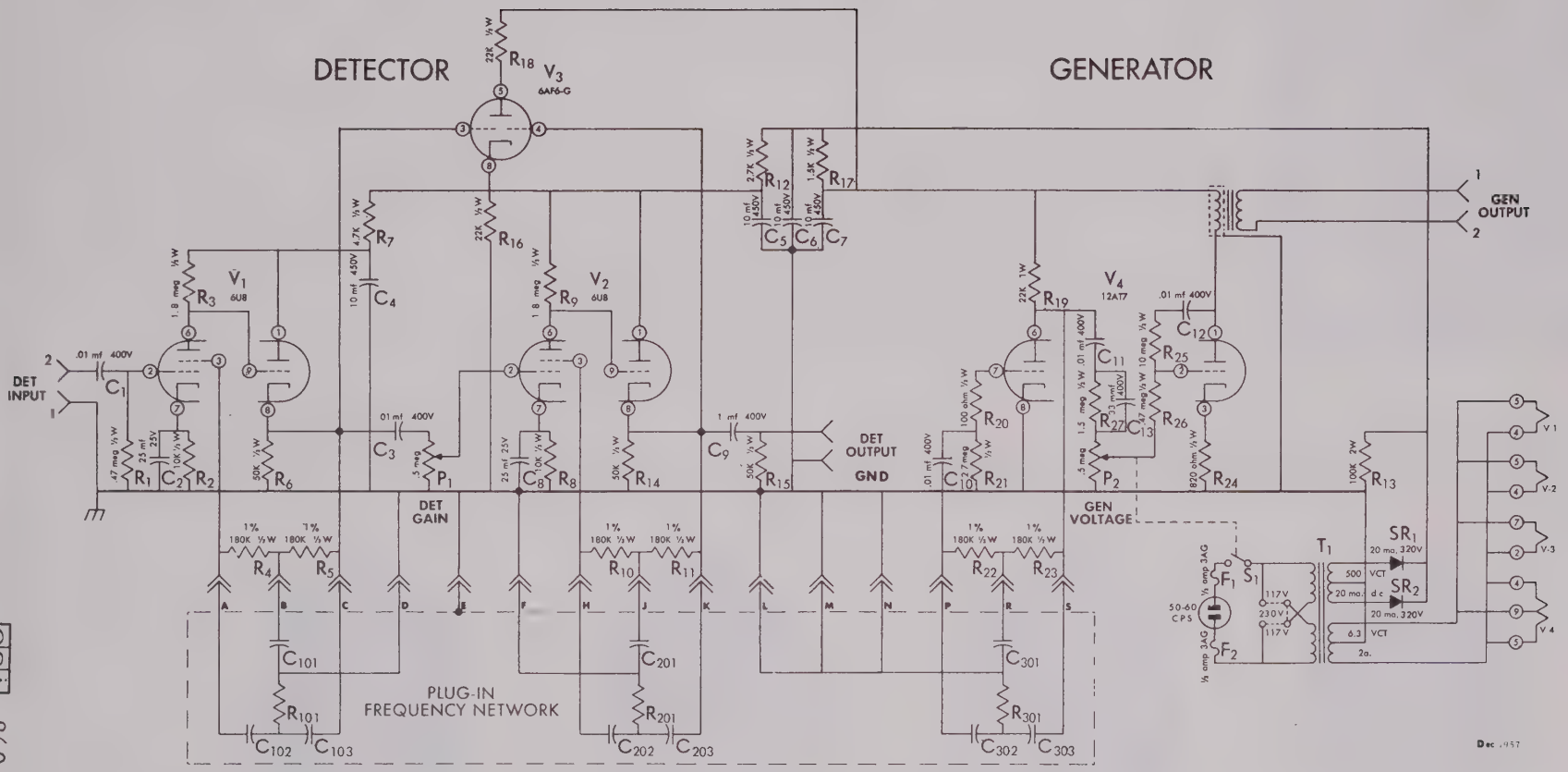
1.2.2 Visual Null Indicator: The dual electron ray null indicator provides an extremely broad range of sensitivity. The upper eye responds to large signals and the lower eye responds to very weak signals. A null is indicated by the maximum opening of both eyes.

1.2.3 Detector Input Terminals: The lower right hand terminals are used for connecting the bridge circuit to the detector. The left hand terminal of this pair is internally grounded at the first stage of the amplifier. To minimize ground loop errors, the bridge circuit should be grounded only through this terminal. The terminal marked GND is connected directly to the panel, and is provided for shield connections.

1.2.4 Detector Output Terminals: The upper left hand terminals are for connecting an oscilloscope or other indicator to the output of the detector amplifier. They are in parallel with the lower eye of the visual null indicator.

2. USING THE 860-R AC GENERATOR AND DETECTOR *the esi way*

CONNECT GENERATOR OUTPUT AND DETECTOR INPUT TO BRIDGE	Set the generator voltage control to off for safety.
SET GENERATOR VOLTAGE CONTROL WITH DOT UP	This turns on the power supply, and provides sufficient generator voltage for most measurements.
SET DETECTOR GAIN CONTROL WITH DOT UP	This provides sufficient detector sensitivity for most measurements.
BALANCE BRIDGE	The null is indicated by maximum opening of both eyes. The pattern edges will be sharp at a null but will remain "fuzzy" for a minimum which is not a true null.
IF ADDITIONAL SENSITIVITY IS NEEDED, INCREASE THE DETECTOR GAIN AND/OR GENERATOR VOLTAGE.	Maximum sensitivity may be needed for bridge measurements of very high or very low impedance components.



3. 860-R AC GENERATOR-DETECTOR CIRCUIT DIAGRAM

ESI Condensed Catalog A-26

MARCH • 1958

Supersedes March, 1957

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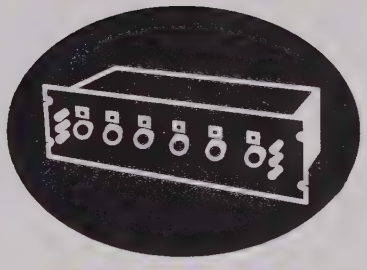
BRIDGES AND ACCESSORIES



VOLTAGE DIVIDERS

DECADE CAPACITORS

DECADE RESISTORS

ELECTRO-MEASUREMENTS, INC.

7524 S. W. MACADAM, PORTLAND, ORE.

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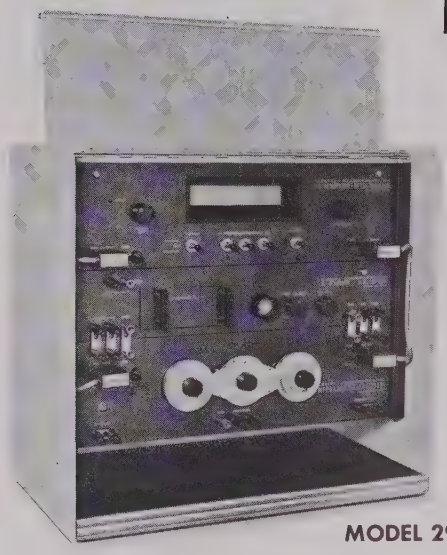
MODEL 291 UNIVERSAL IMPEDANCE BRIDGE



MODEL 291

THE ESI MODEL 291 bridge is a rack-mounted general purpose impedance bridge. It offers high accuracy and great flexibility of measurement. The controls have been human engineered for maximum operator convenience. Simple operation and error-free direct-line readout are made possible by the ESI DEKADIAL® coaxial control. The bridge measures resistance, conductance, capacitance and inductance. For capacitors and inductors, it also measures the dissipation factor (D) and storage factor (Q). The ESI Model 291 bridge consists of a Model 290-R Universal Impedance Bridge, a Model 840-R DC Generator-Detector and a Model 860-R AC Generator-Detector mounted in a specially designed cabinet as illustrated.

The main DEKADIAL® assembly of the 290-R bridge unit provides the equivalent of 12,000 dial divisions on any range. Terminals are provided for the connection of an external generator and detector. This permits measurement of capacitance or incremental inductance with dc superimposed.

MODEL 291, including generators, cabinet and cables.
MOUNTING: Custom designed cabinet. 12″ deep, 19½″ wide, 20″ high.
WEIGHT: 55 lbs. net.
PRICE: $775.00 f.o.b. Portland, Oregon.

MODEL 290-R bridge unit for rack mounting.
MOUNTING: Standard relay-rack panel, 5¼″ x 19″; depth behind panel approximately 8″.
WEIGHT: 18½ lbs. net.
PRICE: $350.00 f.o.b. Portland.

MODEL 290-R IMPEDANCE BRIDGE

RESISTANCE: 0 to 1.2 megohms; 0.1 milliohm per dial division on lowest range. Equivalent resistance measurements to 10,000 megohms are possible using the conductance ranges. Accuracy: ±(0.10% plus 1 dial division)*

CONDUCTANCE: 0 to 1.2 mhos; 100 micromicromhos per dial division on lowest range (this is the conductance of a 10,000 megohm resistor). Accuracy: ±(0.10% plus 1 dial division)*

CAPACITANCE: 0 to 1,200 microfarads. 0.1 micromicrofarad per dial division on lowest range. Accuracy: ±(0.20% plus 1 dial division)*

INDUCTANCE: 0 to 1,200 henrys; 0.1 microhenry per dial division on lowest range. Accuracy: ±(0.30% plus 1 dial division)*

RECOMMENDED FREQUENCY RANGE: Resistance or conductance—dc and low audio frequency; capacitance or inductance—100 cps to 10 kc.

MODEL 840-R DC GENERATOR-DETECTOR

THE ESI MODEL 840-R is a line-operated dc power supply and galvanometer unit for use in dc bridge measurements. It contains high and low voltage dc power supplies with limiting resistors, a voltage selector switch and a polarity reversing switch. The light beam galvanometer has a sensitivity of 0.03 microamperes per millimeter. Galvanometer damping and sensitivity control switches are provided.

MOUNTING: Standard relay-rack panel, 5¼″ x 19″. Depth behind panel approximately 8″.
WEIGHT: 12 lbs. net.
PRICE: $175.00 f.o.b. Portland, Oregon.

MODEL 860-R AC GENERATOR-DETECTOR

THE MODEL 860-R unit is a line-operated audio frequency generator and high gain null-detector for use in ac bridge measurements. The detector is sharply tuned for rejection of harmonics and noise and has a dual electron-ray tube for visual null indication over a wide range of input voltages. Its sensitivity provides visible indication of signals which are 20 microvolts or less. The operating frequency is controlled by a plug-in tuning network. A 1 kilocycle unit is supplied. Auxiliary plug-in networks are available for any frequency from 100 cycles to 10 kilocycles.

MOUNTING: Standard relay-rack panel, 3½″ x 19″; depth behind panel approximately 8″.
WEIGHT: 10 lbs. net.
PRICE: $170.00 f.o.b. Portland, Oregon.

MODEL 250 UNIVERSAL IMPEDANCE BRIDGE

MODEL 250-DA

THE MODEL 250-DA is a general purpose bridge for dc and audio frequency measurements of resistance, capacitance and dissipation factor (D), inductance and storage factor (Q). It is mounted in a rugged, compact case with a lid containing operating instructions. The bridge contains a line-operated power supply, a sensitive galvanometer, a vacuum tube ac generator and a high gain ac amplifier with an electron-ray tube visual null indicator. The main DEKADIAL® concentric dial assembly is equivalent to 12,000 dial divisions on any range.

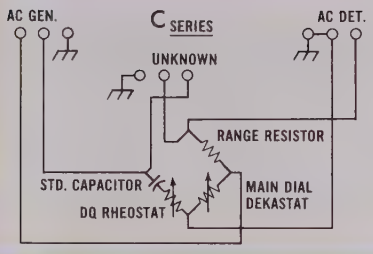
RESISTANCE: 0 to 12 megohms in 8 ranges; 0.1 milliohm per dial division on lowest range. Accuracy: ±(0.10% plus 1 dial division)*
CAPACITANCE: 0 to 1200 microfarads in 7 ranges; 0.1 micromicrofarad per dial division on lowest range. Accuracy: ±(0.25% plus 1 dial division)*
INDUCTANCE: 0 to 1200 henrys in 7 ranges; 0.1 microhenry per dial division on lowest range. Accuracy: ±(0.9% plus 1 dial division)*

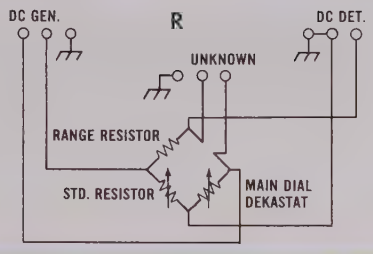
OPERATING FREQUENCY: 1 kilocycle with tuning networks supplied. Other networks available for any frequency between 100 cycles and 10 kilocycles.
DIMENSIONS: 9″ deep x 10½″ high x 11″ wide.
WEIGHT: 17½ lbs. net.
PRICE: $495.00 f.o.b. Portland, Oregon.

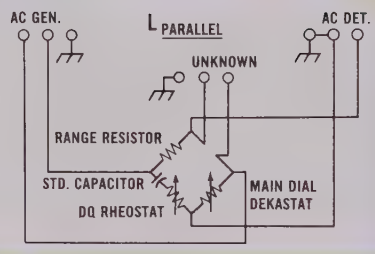
THE MODEL 250-C1 bridge is similar to the Model 250-DA except that it is battery operated and employs a 1 kilocycle microphone hummer for ac measurements. An external ac detector must be provided. For laboratory use the battery may be replaced by the Model 855-A1 Amplifier-Oscillator Unit which makes the unit self contained for both dc and ac measurements.

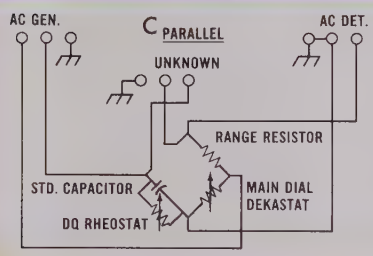
DIMENSIONS: 9″ deep x 10½″ high x 11″ wide.
WEIGHT: 15 lbs. net.
PRICE: $340.00 f.o.b. Portland, Oregon.

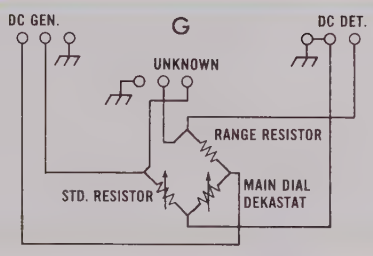
* Slightly larger errors may be encountered on the highest and lowest ranges or at frequency extremes.

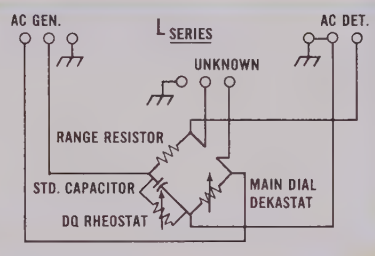




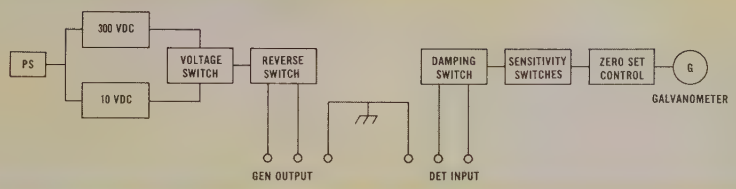




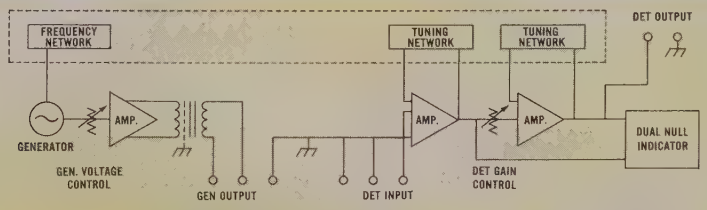




MODEL 840-R
D. C. GENERATOR-DETECTOR
BLOCK DIAGRAM



MODEL 860-R
A. C. GENERATOR-DETECTOR
BLOCK DIAGRAM

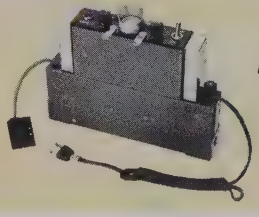


MODEL 855-A1 AMPLIFIER-OSCILLATOR.

THE MODEL 855-A1 is a line-operated generator detector unit especially designed as an accessory for the ESI Model 250-C1 Impedance Bridge. It contains a line-operated power supply, a vacuum tube ac generator and a high gain ac amplifier with an electron-ray tube visual null indicator.

AMPLIFIER GAIN: Approximately 65 db.
SECOND HARMONIC REJECTION: Approx. 20 db.
OPERATING FREQUENCY: 1 kilocycle with tuning networks supplied. Other networks available for any frequency between 100 cycles and 10 kilocycles.

DIMENSIONS: 1½" x 7½" x 9¾".
WEIGHT: 4 lbs. net.
PRICE: $170.00 f.o.b. Portland, Oregon.



MODEL 855-A1

esi excellent scientific instruments

MODEL 260

MODEL 260 COMPARISON BRIDGE

THE MODEL 260 is a precision audio-frequency bridge for comparing resistive, capacitive or inductive components against a suitable standard in terms of both magnitude and phase angle. The main control grouping is designed for simultaneous adjustment of phase and magnitude dials. The controls are clearly identified and conveniently arranged. In-line readings of percentage variation and multiplier factors reduce the chance of human error.

MAGNITUDE DIFFERENCE RANGES: ±0.3%, ±3.0%, and ±30% of the magnitude of the standard; 0.01% per dial division on lowest range.
PHASE DIFFERENCE RANGES: ±0.15%, ±1.5%, and ±15% of a radian; 0.01% per dial division on lowest range.
BASIC ACCURACY: ±1 dial division on either dial.
IMPEDANCE RANGE: Limited essentially by the sensitivity of the null indication; the sensitivity is sufficient to allow over-all accuracy of ±0.01% for impedances between 20 ohms and 2 megohms, and for accuracy of ±1% at 0.2 ohms and 200 megohms.
GENERATOR-DETECTOR: Same characteristics as Model 860-R ac Generator-Detector.
DIMENSION: 11" wide x 8½" high x 7½" deep. Can be supplied for rack mounting on special order.
NET WEIGHT: 19 lbs.
PRICE: $445.00 f.o.b. Portland, Oregon.

MODEL 270

MODEL 270 CAPACITANCE BRIDGE

THE MODEL 270 Capacitance Bridge is a portable self-contained instrument for the rapid and accurate measurement of capacitance and dissipation factor over a wide range of values.

No correction is necessary for zero capacitance within the bridge. The bridge has internal shielding which eliminates stray capacitance in parallel with the unknown. This feature makes possible measurement of small three-terminal capacitors to an accurcy of 0.01 micromicrofarads without the use of a separate guard circuit or Wagner ground. A shield lead can be used to eliminate test lead capacitance. The exclusive ESI DEKADIAL® assembly provides direct in-line readings of capacitance and dissipation factor. The equivalent of 12,000 dial divisions of resolution are available on each capacitance range.

CAPACITANCE: 0 to 120 microfarads in seven ranges; 0.01 micromicrofarads per dial division on lowest range. Accuracy: On the five intermediate ranges: ±(0.1% plus 1 dial division). On highest range and lowest range: ±(0.2% plus 1 dial division). Accuracy ratings apply at a frequency of 1 kilocycle and a temperature of 25°C. Capacitance accuracy specifications apply when the bridge has been recently standardized against a reference standard capacitor. The long term drift in calibration will not exceed 0.1% per year, and any such drift can be corrected by a single adjustment to restandardize the bridge against any certified reference capacitor.
DISSIPATION FACTOR: 0 to 1.05 times frequency in kilocycles in three ranges 0.0001 per dial division on lowest range. Accuracy: ±(2% plus 0.0005) at 1 kilocycle.
GENERATOR-DETECTOR: Same characteristics as Model 860-R ac Generator-Detector.
DIMENSIONS: 11" wide x 8½" high x 7½" deep. Can be supplied for rack mounting on special order.
WEIGHT: 19 lbs. net.
PRICE: $455.00 f.o.b. Portland, Oregon.

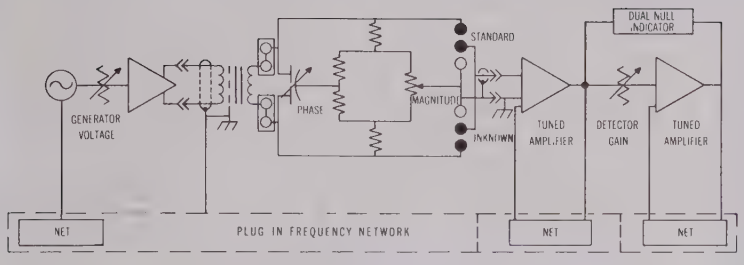
MODEL 230

MODEL 230 WHEATSTONE BRIDGE

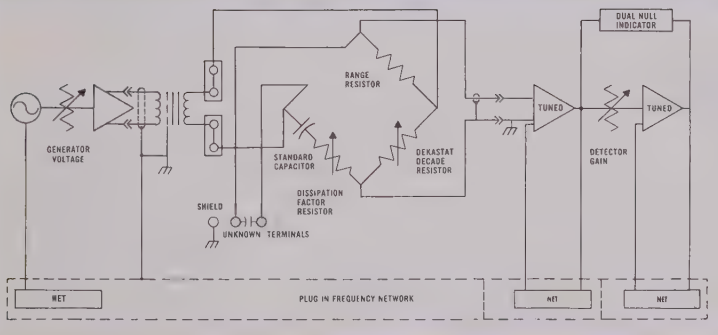
THE MODEL 230 Resistance Bridge is a precision Wheatstone bridge for rack mounting. It offers exceptional accuracy and flexibility for dc resistance measurement. Its simple operation and error-free in-line readout have been achieved by a carefully planned design and control arrangement. A guarded construction is used to permit accurate high resistance measurements in the presence of leakage resistance. Resistance values can be read to five places. The lowest range has a resolution of 10 micro-ohms and the highest range measures to 12 kilomegohms.

RESISTANCE: 0 to 12 kilomegohms in 11 ranges. 10 micro-ohms per dial division on the lowest range. Accuracy: ±(0.02% plus 1 dial division).
DIMENSIONS: Standard Relay-Rack Panel 7" x 19". Depth behind panel approximately 7".
WEIGHT: 10 lbs. net.
PRICE: $450.00.

new



MODEL 260 COMPARISON BRIDGE BLOCK DIAGRAM



MODEL 270 CAPACITANCE BRIDGE BLOCK DIAGRAM

Both the Model 260 Comparison Bridge and the Model 270 Capacitance Bridge are housed in attractive metal cases supported by an adjustable metal stand so that they may be readily positioned for most convenient operation. The bridge stand supports the component terminals 5 inches above the bench or working surface keeping them free from any obstruction. Tilt adjustment can be made for best viewing position. The legs can be folded back to allow shelf storage of the instrument with a minimum of storage area. In this position the stand becomes a carrying handle.

MODEL 210 DEKABRIDGE® WHEATSTONE BRIDGE

THE MODEL 210 is a compact Wheatstone Bridge for use with an external power supply and a galvanometer. The convenient DEKA-DIAL assembly provides for four place readings on each of the seven ranges. Measurements can be made from 1 milliohm per dial step on the lowest range to a maximum of 12 megohms on the highest range.

ACCURACY: ±0.1%.
DIMENSIONS: 7½" wide x 5½" high x 5½" deep.
WEIGHT: 7½ lbs. net.
PRICE: $140.00 f.o.b. Portland, Oregon.

MODEL 210

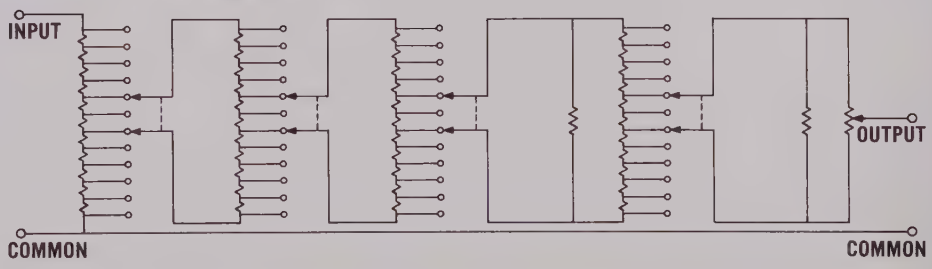
MODEL DT-45 DEKATRAN DECADE VOLTAGE DIVIDER

MODEL DT-45

THE MODEL DT-45 is a precision voltage divider for panel mounting. A three decade ratio transformer and an interpolating potentiometer provide 5 place readings of voltage ratio. This divider features the exclusive DEKADIAL concentric dial arrangement which avoids confusion during adjustment and provides a convenient straight-line reading.

FREQUENCY RANGE: 50 cycles to 10 kilocycles.
LINEARITY: ±0.002% below 3 kilocycles.
NUMBER OF DECADES: 3 transformer decades plus 100 division interpolating potentiometer.
INPUT VOLTAGE: 0.35 volts per cycle below 1 kilocycle, 350 volts maximum above 1 kilocycle.
DIMENSIONS: 3½" square, 6" behind panel, 3¼" mounting hole.
WEIGHT: 3 lbs. net.
PRICE: $275.00 f.o.b. Portland, Oregon.

KELVIN-VARLEY CIRCUIT



The Kelvin-Varley voltage divider circuit contains one or more decades of precision fixed resistors and an interpolating potentiometer to provide high resolution and accurate voltage division. The accuracy of voltage division is expressed in terms of linearity which is defined as the maximum error in output voltage expressed in percent or parts per million (ppm) of the input voltage. This definition of linearity is comparable to the definition of terminal linearity for a continuous potentiometer.

This voltage divider circuit is suitable for both dc and ac operation. The linearity specifications for each model applies to dc and low frequency ac. The frequency at which additional ac error becomes appreciable depends on the model and the input resistance. For example, a 10,000 ohm Model DP-211 remains within its linearity specification from dc to approximately 10 kc. Its phase shift is about ½ degree at 10 kc or approximately 1 minute at 400 cycles.

MODEL EP-A ESIPOT POTENTIOMETER

THE MODEL EP-A is a miniature uncalibrated voltage divider. It contains a single turn potentiometer which at the end of its travel actuates a decade switch to give resolution equivalent to a ten turn potentiometer. A knob and shaft lock are available but are not included.

AVAILABLE INPUT RESISTANCES: 1 K, 10 K, 100 K, 1 Meg. and 10 Meg.

DIMENSIONS: Diameter 1¾", behind panel depth 2", mounting hole ⅜".

PRICE: $9.00 f.o.b. Portland, Oregon.

Decade Voltage Dividers

MODEL RV DEKAVIDER® DECADE VOLTAGE DIVIDERS

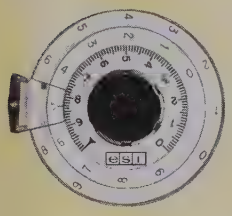
These voltage dividers for rack mounting contain very closely matched precision resistors for maximum accuracy. Model RV-622 is enclosed by a metal box which serves as a dust cover and shield. Model RV-632 is constructed with an additional internal shield which is driven by a voltage divider ganged to the precision divider. This driven shield provides a substantial decrease in phase shift and some improvement in voltage accuracy for ac operation.

MODEL DV DEKAVIDER® DECADE VOLTAGE DIVIDERS.

These precision decade voltage dividers are mounted on an adjustable base and are provided with clearly marked input and output binding posts for convenient laboratory use.

MODEL DP DEKAPOT® DECADE POTENTIOMETERS.

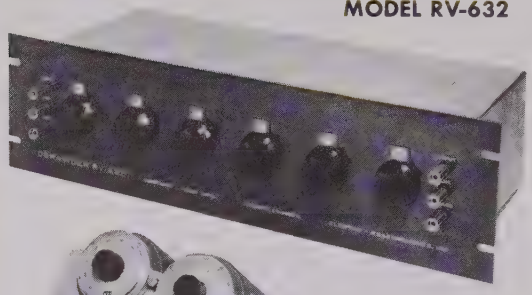
These precision decade voltage dividers are designed for panel mounting. The exclusive ESI DEKADIAL concentric dial is used for convenient straight-line readings.

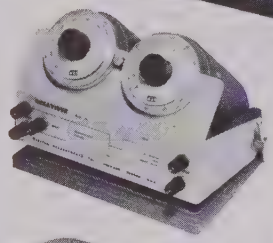


THE ESI DEKADIAL®

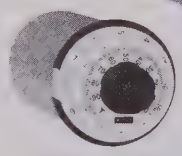
The unique patented ESI DEKADIAL provides outstanding accuracy of reading and convenience of operation. The compact coaxial assembly of individual dials permits rapid setting of the required value with a minimum of physical effort and visual attention. The independently operated dials provide both the coarse initial steps for quickly approximating the required value and progressively finer steps for more exact setting. For added convenience in setting, the dials may be rotated continuously in either direction unless the application requires the use of stops. Reading errors are minimized by presenting the information as a series of numbers read from left to right in a single horizontal line.

MODEL RV-632

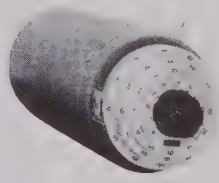




MODEL DV- 411



MODEL DP-213



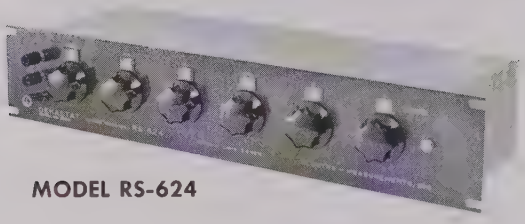
MODEL DP-311

KELVIN-VARLEY
DECADE VOLTAGE DIVIDERS

Type		DEKAVIDERS®				DEKAPOTS®					
Mounting		Rack		Base		Panel					
Model		RV-622	RV-632	DV-411	DV-412	DP-111	DP-115	DP-211	DP-212	DP-213	DP-311
Package Style		A	A	B	B	D	D	D	D	E	D
Dimension a		19″	19″	7.5″	7.5″	3″	2″	3″	3″	2.25″	3″
Dimension b		7″	7″	5.5″	5.5″	3.8″	2″	5.9″	7″	4″	7″
Dimension c		3.5″	5.25″	5.5″	5.5″	——	——	——	——	——	——
Size of Mounting Hole		——	——	——	——	0.438″	0.375″	0.438″	0.438″	2.375″	0.438″
Weight in lbs. net		8	9	7.5	7.5	0.75	0.5	1.25	0.75	1	1.5
Linearity		±0.0025%	±0.0025%	±0.005%	±0.005%	±0.1%	±0.1%	±0.01%	±0.005%	±0.01%	±0.005%
Resolution		0.0001%	0.0001%	0.0003%	0.01%	0.03%	0.03%	0.003%	0.1%	0.003%	0.0003%
Number of Decades		6	6	3 plus 100 Div. Pot.	4	1 plus 100 Div. Pot.	1 plus 100 Div. Pot.	2 plus 100 Div. Pot.	3	2 plus 100 Div. Pot.	3 plus 100 Div. Pot.
Input Power Rating		5W	5W	5W	5W	5W	3W	5W	5W	3W	5W
STANDARD VALUES	Input Resistance	——	——	——	——	100Ω	——	——	——	——	——
	Price°	——	——	——	——	$65.00	——	——	——	——	——
	Input Resistance	——	——	——	——	1K	1K	1K	1K	——	——
	Price°	——	——	——	——	$65.00	$69.00	$104.00	$110.00	——	——
	Input Resistance	10K*	§5K/10K*	10K*	10K*	10K*	10K*	10K*	10K*	10K*	10K*
*Value for Best Delivery	Price°	$395.00	$465.00	$132.00	$132.00	$59.00	$69.00	$98.00	$104.00	$129.00	$158.00
	Input Resistance	——	——	100K	100K	100K	——	100K	100K	——	100K
	Price°	——	——	$145.00	$145.00	$68.00	——	$108.00	$114.00	——	$171.00

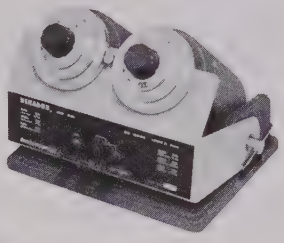
°f.o.b. Portland, Oregon §5K With Internal Guard Drive Connected, 10K With Internal Guard Drive Disconnected

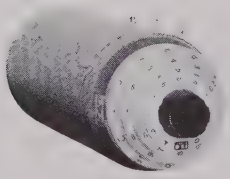
DECADE RESISTORS



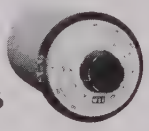
MODEL RS-624

MODEL DB-655





MODEL DS-464



MODEL DS-366

DEKASTAT® and **DEKABOX**® decade resistors are adjustable resistance standards of high accuracy. They contain one or more decades of precision fixed resistors and some models include an interpolating rheostat. The resistors are wound with wire which has a temperature coefficient of less than ±0.002% per degree centigrade, and are adjusted to extremely close tolerances after being put through a special aging process. A unifilar winding on a thin mica card is used wherever possible. For high resistance values a non-inductive winding on a ceramic bobbin is used. These resistors provide high accuracy, excellent long term stability and low residual reactance.

Accuracy ratings include the effects of normal temperature variations and long term drift. At the time of final inspection the accuracy at 25 degrees centigrade with negligible power dissipation is much better than the values shown in the table. A 0.05% term in the ratings is held to better than 0.03%. A 0.02% term is held to better than 0.005%.

MODEL RS DEKASTAT® DECADE RESISTORS.

These decade resistance units for rack mounting contain precision resistors adjusted to especially close tolerances for use as laboratory resistance standards.

MODEL DB DEKABOX® DECADE RESISTORS.

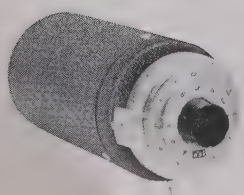
These precision decade resistors are mounted on an adjustable base and are provided with clearly marked binding posts for convenient laboratory use.

MODEL DS DEKASTAT® DECADE RESISTORS.

These precision decade resistors are designed for panel mounting. The ESI DEKADIAL concentric dial is used for convenient straight-line readings.

DECADE CAPACITORS

MODEL DC-40



MODEL DK-30

DEKAPACITOR® and **DEKABOX**® capacitors are adjustable decade units. They contain hermetically sealed polystyrene capacitors except for values below 1,000 micromicrofarads where high quality ceramic or mica capacitors are used.

MODEL DC DEKABOX® DECADE CAPACITORS.

These decade capacitors are mounted on an adjustable base and are provided with binding posts for laboratory use.

MODEL DK DEKAPACITOR® DECADE CAPACITORS.

These decade capacitors are designed for panel mounting. The ESI DEKADIAL is used for straight-line readings.

Decade Resistors and Capacitors

DECADE RESISTANCE UNITS

Type		DEKASTAT®	DEKABOX®			DEKASTAT®					
Mounting		Rack	Base			Panel					
Model		RS-624	DB-265	DB-365	DB-655	DS-160	DS-165	DS-265	DS-365	DS-366	DS-464
Package Style		A	C	C	B	D	D	D	D	E	D
Dimension a		19″	4.5″	4.5″	7.5″	3″	3″	3″	3″	2.25″	3″
Dimension b		7″	5.5″	5.5″	5.5″	3.8″	3.8″	3.8″	3.8″	4″	7″
Dimension c		3.5″	5.5″	5.5″	5.5″	——	——	——	——	——	——
Size of Mounting Hole		——	——	——	——	0.438″	0.438″	0.438″	0.438″	2.375″	0.438″
Weight in lbs. net		8	4.75	4.75	7.5	0.75	0.75	1	1	1	1.5
Accuracy (After Corr. for Zero Resist.)		±(0.02% +5 mΩ)	±(0.05% +1 dial div.)	±(0.05% +5 mΩ)	±(0.05% +10 mΩ)	±(0.05% +1 dial div.)	±(0.05% +3 mΩ)	±(0.05% +1 dial div.)	±(0.05% +5 mΩ)	±(0.05% +5 mΩ)	±(0.05% +7 mΩ)
Approximate Zero Resistance		0.030Ω	0.030Ω	0.015Ω	0.030Ω	0.025Ω	0.010Ω	0.030Ω	0.015Ω	0.015Ω	0.020Ω
Number of Decades		6	2 plus 105 Div. Rheo.	3	6	1 plus 105 Div. Rheo.	2	2 plus 105 Div. Rheo.	3	3	4
Power Rating of Individual Steps		0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.5W	0.2W	0.5W
STANDARD VALUES	Total Resistance	——	——	——	——	——	119Ω	——	——	——	——
	Small. Step or Dial Div.	——	——	——	——	——	1Ω	——	——	——	——
	Price°	——	——	——	——	——	$55.00	——	——	——	——
	Total Resistance	——	——	1,199Ω	——	1.2K*	1,190Ω	——	1,199Ω	——	——
	Small. Step or Dial Div.	——	——	1Ω	——	1Ω	10Ω	——	1Ω	——	——
	Price°	——	——	$69.00	——	$50.00	$52.00	——	$69.00	——	——
	Total Resistance	——	12K*	11,990Ω*	——	12K	11,900Ω*	12K*	11,990Ω*	11,990Ω*	11,999Ω*
	Small. Step or Dial Div.	——	1Ω	10Ω	——	10Ω	100Ω	1Ω	10Ω	10Ω	1Ω
	Price°	——	$68.00	$66.00	——	$45.00	$48.00	$63.00	$66.00	$96.00	$110.00
	Total Resistance	——	120K	119,900Ω	——	120K	119,000Ω	120K	119,900Ω	——	——
	Small. Step or Dial Div.	——	10Ω	100Ω	——	100Ω	1K	10Ω	100Ω	——	——
	Price°	——	$77.00	$75.00	——	$55.00	$59.00	$72.00	$75.00	——	——
	Total Resistance	1.2 MEG*	——	——	1,199,999Ω*	——	——	——	——	——	——
	Small. Step or Dial Div.	1Ω	——	——	1Ω	——	——	——	——	——	——
	Price°	$425.00	——	——	$151.00	——	——	——	——	——	——

°f.o.b. Portland, Oregon *Value for best delivery

DECADE CAPACITANCE UNITS

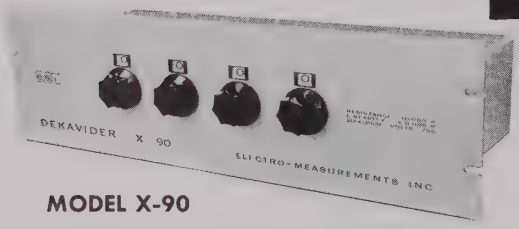
Type		Dekabox®	Dekapacitor®
Mounting		Base	Panel
Model		DC-40	DK-30
Package Style		B	D
Dimension a		7.5″	3″
Dimension b		5.5″	5.9″
Dimension c		5.5″	——
Size of Mounting Hole		——	0.438″
Weight in lbs. net		8	1.5
Accuracy (After Corr. for Zero Cap.)		±(1% +5 μμf)	±(1% +5 μμf)
Approximate Zero Capacitance		30 μμf	20 μμf
Number of Decades		4	3
Voltage Rating		400V DC	400V DC
STANDARD VALUES	Total Capacitance	1 μf	1 μf
	Smallest Step	100 μμf	1,000 μμf
	Price°	$195.00	$170.00

°f.o.b. Portland, Oregon

Special Products

The ESI Special Products Department has been created to speed production on items built to customer specification and on ESI designed items for which the demand does not justify large scale production. The group is also responsible for pilot production of new items. Examples of the work of the Special Products Department are shown on this page. We are always happy to discuss YOUR problems on this basis.

REMOTELY CONTROLLED VOLTAGE DIVIDER

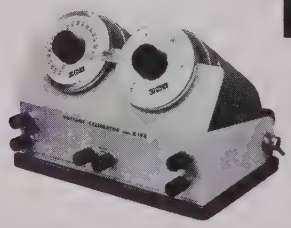


MODEL X-90

THE MODEL X-90 DEKAVIDER® is electrically equivalent to the standard ESI Model DV-411 Voltage Divider. It is rack mounted and can be either set by knobs from the front of the panel or programmed electrically by Ledex drive units mounted on the other end of the shafts. This divider represents a mechanical adaptation of a standard ESI product.

VOLTAGE CALIBRATOR

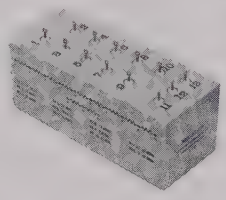
MODEL X-194



THE MODEL X-194 Voltage calibrator supplies specified voltages at the output terminals when a 500 volt input is adjusted to balance the calibration output against a standard cell. The left-hand dial is set to the voltage indicated on the standard cell certificate and the right-hand dial is set to the desired output voltage. These units are certified at the time of shipment to an accuracy of ±0.005%. This calibrator represents an electrical and mechanical design for a customer's specific application.

RESISTANCE DIVIDER UNIT

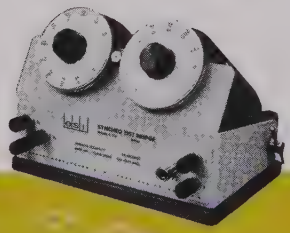
MODEL X-130



THE MODEL X-130 is a precision high stability voltage divider plus a pair of matched resistors furnished in a hermetically sealed unit. This unit must hold its voltage ratio to ±0.01% over the temperature range of +65 degrees Fahrenheit to +110 degrees Fahrenheit at any frequency from dc to 400 cycles with up to 0.1 watts of power dissipation. This divider represents the solution to a problem in temperature coefficient matching and special packaging.

SYNCHRO AND RESOLVER BRIDGES

MODEL X-210



Both Synchro and Resolver Test bridges are made to test units in accordance with the military specifications for electrical position accuracy. These bridge types can be supplied with angular steps of 2½ degrees, 5 degrees or 10 degrees to an accuracy of 5 seconds of arc. These test bridges represent instruments for which the demand does not yet justify large scale production.

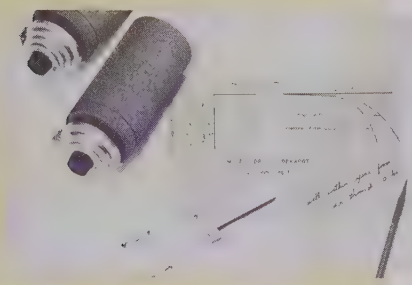
THE DIAGRAM SHOWN IS FOR A 10° INTERVAL UNIT.

ELECTRO-MEASUREMENTS, INC.

...where instruments are built with YOU in mind!

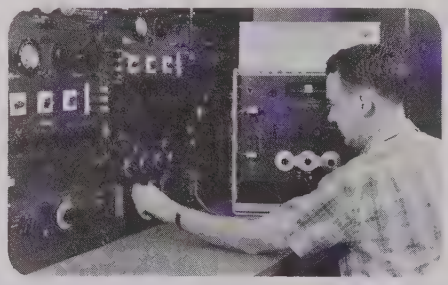
ENGINEERING

Our aim at ESI is to conceive, design and build instruments which will give you genuine satisfaction under prolonged use. To achieve this result, we invest well above the industry average in research and development to insure that the latest in circuits, materials and manufacturing techniques go into our equipment designs. We emphasize "human engineering" to increase operational accuracy and convenience. In short, engineering at ESI is directed toward balanced designs considering all factors of application, cost and the state of the art.



SERVICE

We enjoy being of service to you. We try to give all of your inquiries courteous attention and prompt reply. We constantly endeavor to improve our order processing and manufacturing schedules to speed our deliveries to you. We provide well trained sales engineers across the country to serve you personally with technical data, delivery information and equipment demonstrations to aid you in careful equipment evaluation before you buy. We maintain fully staffed and equipped repair facilities at our plant and in key cities near you to insure rapid repair and calibration service and to modernize and extend the life of your ESI equipment.



INTEGRITY

We try to describe our equipment to you with accurate and conservative specifications. We expect you to expect our instruments to be better than the published specifications.

We back up our equipment with a liberal written warranty. More important, we back it up with careful quality control and rigorous testing. Our purpose is to warrant your complete satisfaction both now and in the future.

We provide stable employment, the best in working conditions, liberal employee benefits and a substantial share in the company profits to the end that each member of the ESI team is motivated toward giving you unexcelled equipment and services. We are as much concerned with the opportunity to provide you with outstanding instrumentation ten years from now as we are in selling you our present equipment.

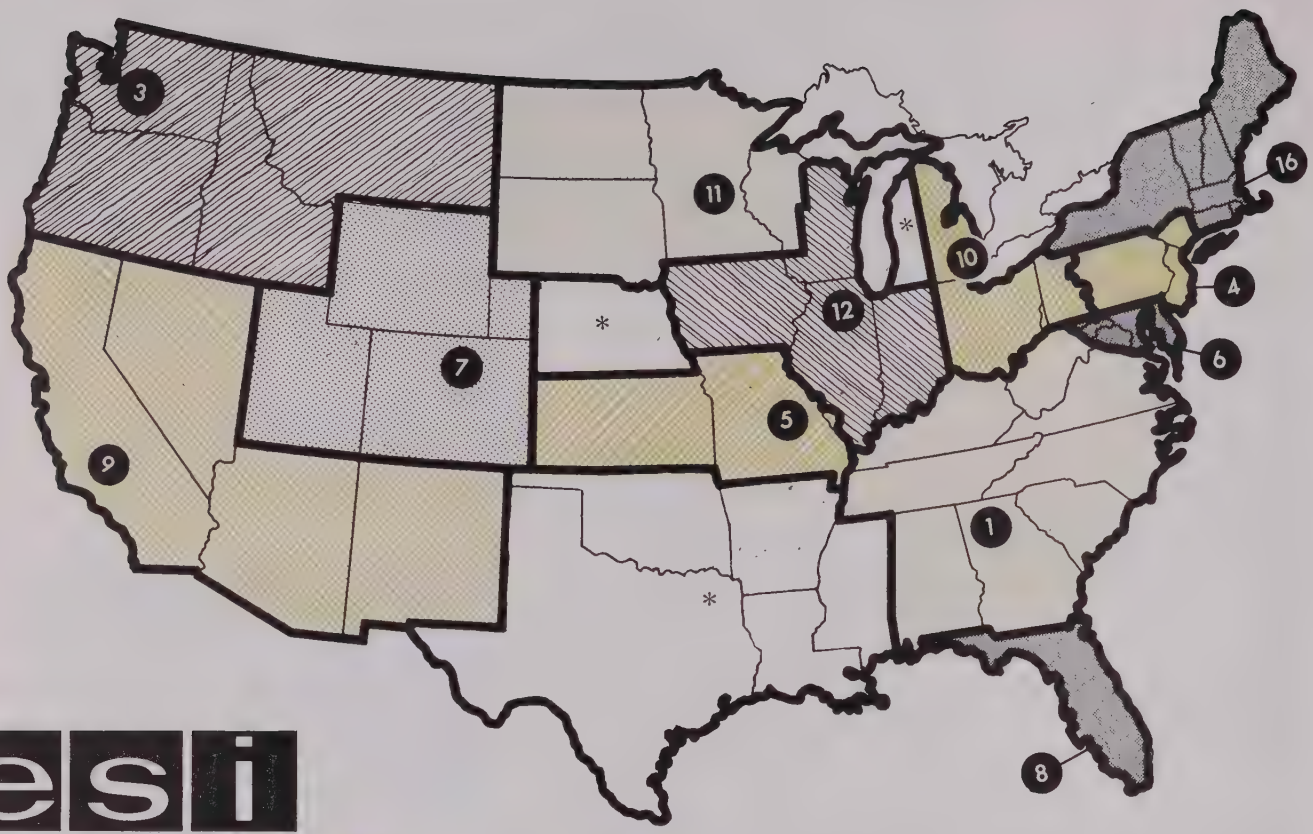
May we be of service to you, today?

WARRANTY

Electro-Measurements, Inc. warrants each instrument and component to be free from defects in material and workmanship. Electro-Measurements, Inc. will service any instrument and replace parts thereof (except tubes, fuses and batteries) which shall within one year after making delivery to the original purchaser, prove to be unsatisfactory.

If the fault has been caused by misuse or abnormal conditions of operation, a nominal charge will be made for repairs. In this case an estimate will be submitted before making such repairs.

Electro-Measurements, Inc. reserves the right to make changes in design at any time without incurring obligation to modify units previously purchased.



esi

Sales Representatives

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3133 Maple Drive, N. E.
Atlanta 5, Georgia

2 **RUSH S. DRAKE ASSOCIATES**
1806 Bush Place
Seattle 44, Washington

4 **G. CURTIS ENGEL AND ASSOCIATES**
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Ridgewood, New Jersey
P. O. Box 4383
Philadelphia 18, Pennsylvania

5 **HARRIS-HANSON COMPANY**
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635 St. Johns Road
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7 **HYTRONIC MEASUREMENT ASSOCIATES**
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Sacramento 14, California

NEELY ENTERPRISES (continued)
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16 **TECHNICAL INSTRUMENTS, INC.**
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174 Grayton Road (Buffalo Office)
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ELECTRO-MEASUREMENTS, INC.

7524 S. W. MACADAM, PORTLAND, ORE.

A-26 ESI 50M

LITHO IN U. S. A.

esi Universal Impedance Bridge

MODEL 291

DC RESISTANCE AND CONDUCTANCE MEASUREMENTS

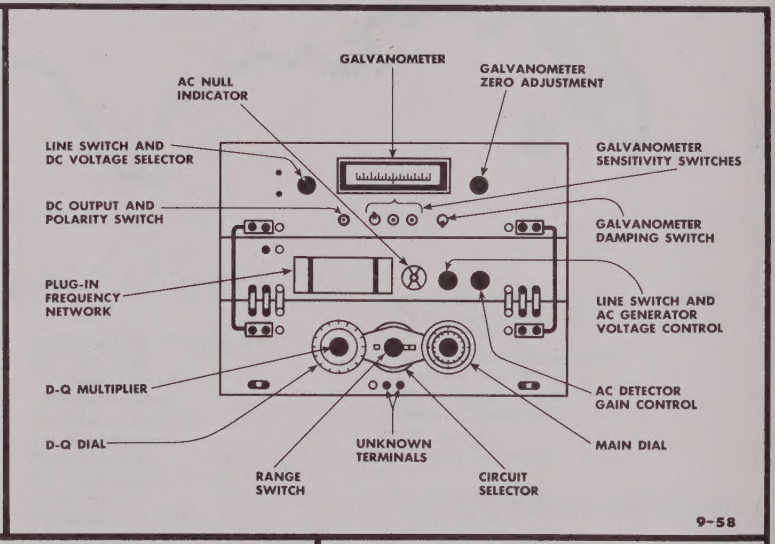
1. Set the Output and Sensitivity Switches to the Center Position (Off).
2. Set the Circuit Selector to R or G.
3. Set the DC Voltage Selector to 10 V.
4. Connect the Resistor to the Unknown Terminals.
5. Adjust the Galvanometer Zero, if necessary.
6. Set the Galvanometer Damping Switch to Position 3.
7. Turn on the lowest Sensitivity Switch. The Switch may be pressed down for momentary contact, or up for locking contact.
8. Set the DC Output Switch to Normal.
9. Set the Main Dial of the Bridge to read 3.000.
10. Adjust first the Range Switch, then the Main Dial, for minimum Galvanometer deflection. Turn on the higher Sensitivity Switches as the null is approached.
11. If the balance is beyond full scale on the highest range, change the Circuit Selector from R to G, or from G to R.
12. If the Main Dial reading at balance is less than 1.200, use the next lower setting of the Range Switch and re-adjust the Main Dial for a null.
13. If the Galvanometer response is sluggish when the highest Sensitivity Switch is on, change the Damping Switch to Position 2 or 1.
14. For increased sensitivity on high resistance measurements set the DC Voltage Selector to 300 V.
15. Return the DC Output and Sensitivity Switches to Off Position before disconnecting the Resistor.

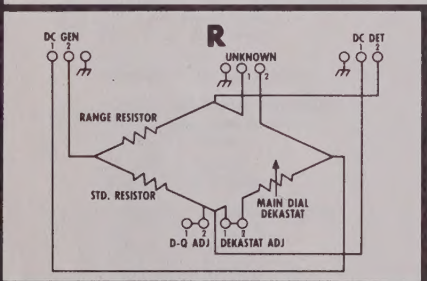
AC CAPACITANCE AND INDUCTANCE MEASUREMENTS

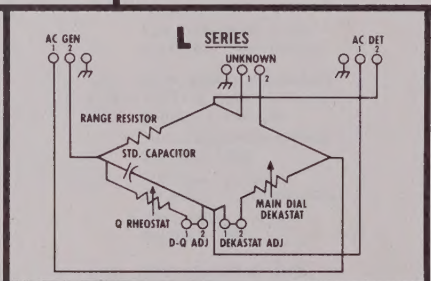
1. Set the Circuit Selector to the appropriate C or L circuit.
2. Connect the Capacitor or Inductor to the Unknown Terminals.
3. Set the Generator Voltage Control with the dot up.
4. Set the Detector Gain Control with the dot up.
5. Set the Main Dial of the Bridge to read 3.000.
6. Set the D-Q Dial to
   0, if the Bridge measures D; or
   100, if the Bridge measures Q.
7. Set the D-Q Multiplier to .1X.
8. Adjust first the Range Switch, then the Main Dial and D-Q Dial, for the widest shadow on the AC Null Indicator. Continue to adjust the Main Dial and D-Q Dial alternately to obtain the widest and sharpest possible shadow.
9. If the balance is beyond full scale on the D-Q Dial, set the Circuit Selector to the other C or L circuit, and repeat from Step 6.
10. If the Main Dial reading at balance is less than 1.200, use the next lower setting of the Range Switch and re-adjust the Main Dial for a null.
11. If the D-Q Dial reading at balance is less than 10, use the next lower setting of the D-Q Multiplier and re-adjust the D-Q Dial for a null.
12. If additional sensitivity is needed, increase the Detector Gain and/or the Generator Voltage.

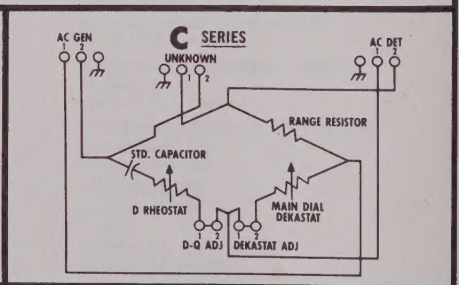
OVERLOAD PROTECTION — The bridge and its associated ac and dc detectors are protected from accidental damage by internal generator power limiting.

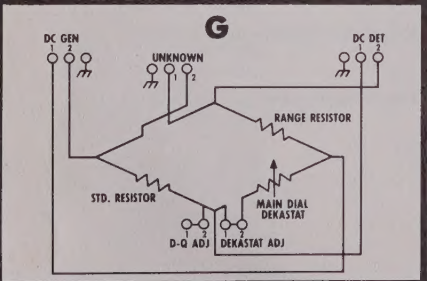
SELECTOR SWITCH SETTING	EQUIVALENT CIRCUIT	CONVERSION EQUATIONS
R	R	$G = \frac{1}{R}$
G	G	$R = \frac{1}{G}$
L Series	L_s, Q	$L_p = L_s \cdot \left(1 + \frac{1}{Q^2}\right)$, $D = \frac{1}{Q}$
L Parallel	L_p, D	$L_s = L_p \cdot \left(\frac{1}{1+D^2}\right)$, $Q = \frac{1}{D}$
C Series	C_s, D	$C_p = C_s \cdot \left(\frac{1}{1+D^2}\right)$, $Q = \frac{1}{D}$
C Parallel	C_p, Q	$C_s = C_p \cdot \left(1 + \frac{1}{Q^2}\right)$, $D = \frac{1}{Q}$

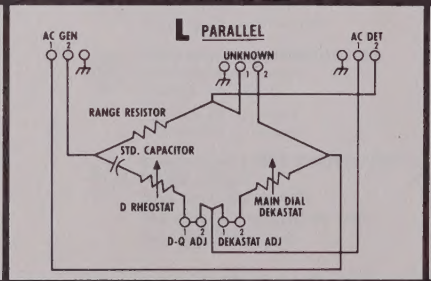


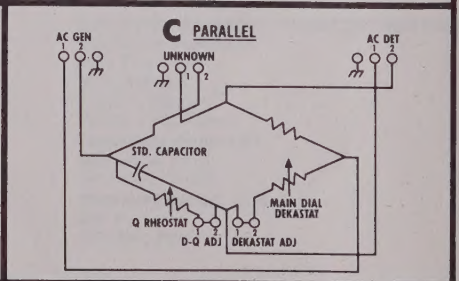












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